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THE JULY SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

JULY, 1935

THE RELATION OF GENETICS TO PHYSIOLOGY AND MEDICINE

NOBEL LECTURE, PRESENTED IN STOCKHOLM ON JUNE 4, 1934

By Dr. THOMAS HUNT MORGAN

DIRECTOR OF THE WM. G. KERCKHOFF LABORATORIES, CALIFORNIA INSTITUTE OF TECHNOLOGY

THE study of heredity, now called genetics, has undergone such an extraordinary development in the present century, both in theory and in practice, that it is not possible in a short address to review even briefly all its outstanding achievements. At most I can do no more than take up a few topics for discussion.

Since the group of men with whom I have worked for twenty years has been interested for the most part in the chromosome-mechanism of heredity, I shall first briefly describe the relation between the facts of heredity and the theory of the gene. Then I should like to discuss one of the physiological problems implied in the theory of the gene; and finally, I hope to say a few words about the applications of genetics to medicine.

The modern theory of genetics dates from the opening years of the present century, with the discovery of Mendel's long-lost paper that had been overlooked for thirty-five years. The data obtained by de Vries in Holland, Correns in Germany and Tschermak in Austria showed that Mendel's laws are not confined to garden peas, but apply to other plants. A year or two later the work of Bateson and Punnett in England and Cuénot in France made it evident that the same laws apply to animals.

In 1902 a young student, William Sutton, working in the laboratory of E. B. Wilson, pointed out clearly and completely that the known behavior of the chromosomes at the time of maturation of the germ-cells furnishes us with a mechanism that accounts for the kind of separation of the hereditary units postulated in Mendel's theory.

The discovery of a mechanism, that suffices to explain both the first and the second law of Mendel, has had far-reaching consequences for genetic theory, especially in relation to the discovery of additional laws; because the recognition of a mechanism that can be seen and followed demands that any extension of Mendel's theories must conform to such a recognized mechanism; and also because the apparent exceptions to Mendel's laws, that came to light before long, might, in the absence of a known mechanism, have called forth purely fictitious modifications of Mendel's laws or even seemed to invalidate their generality. We now know that some of these "exceptions" are due to newly discovered and demonstrable properties of the chromosome mechanism, and others to recognizable irregularities in the machine.

Mendel knew of no processes taking place in the formation of pollen and egg-

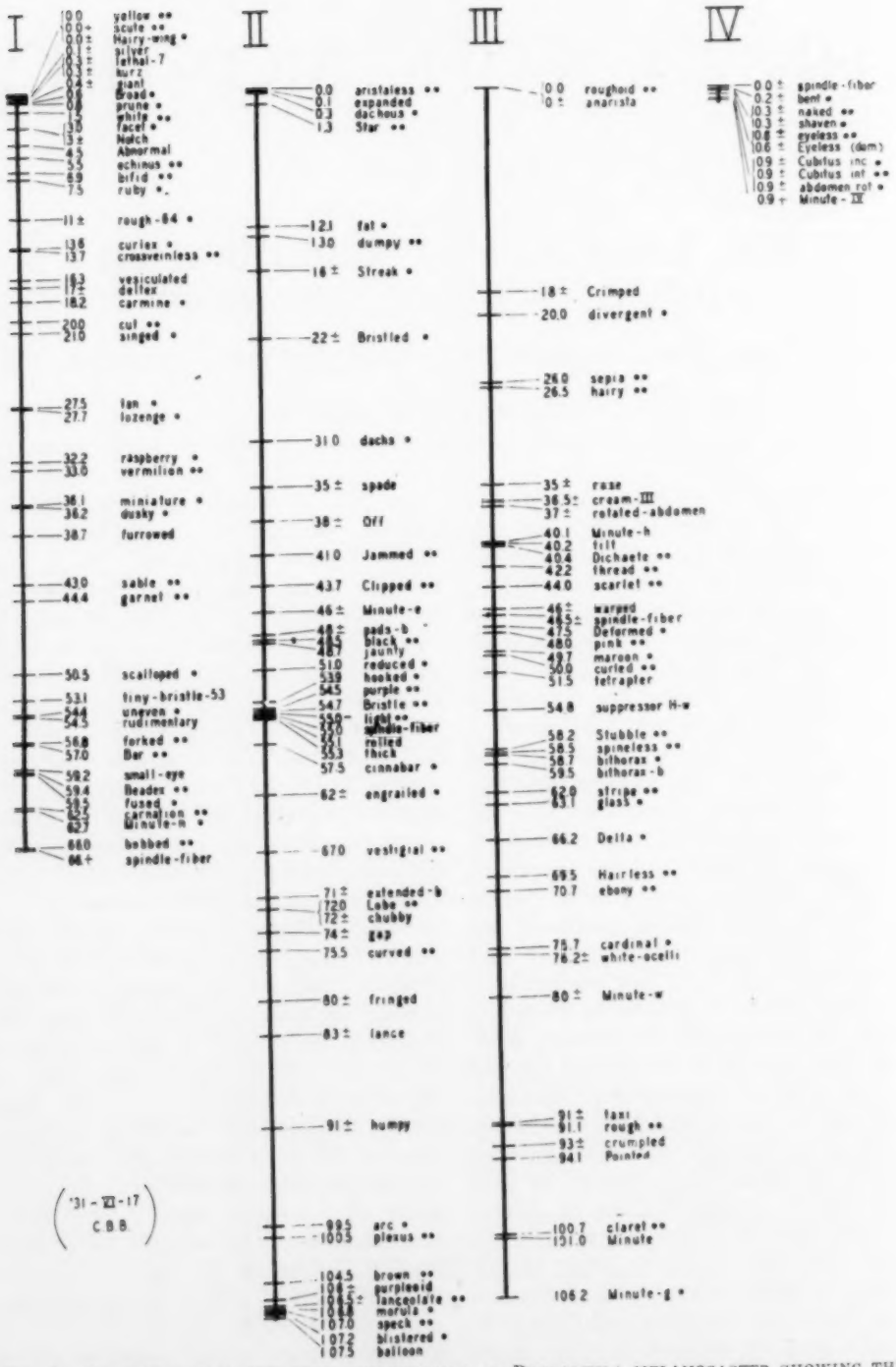


FIG. 1. GENETIC MAP OF THE FOUR CHROMOSOMES OF DROSOPHILA MELANOGASTER SHOWING THE LINEAR ORDER AND RELATIVE DISTANCE APART OF THE GENES. (AFTER BRIDGES.)

cell that could furnish a basis for his primary assumption that the hereditary elements separate in the germ-cells in such a way that each ripe germ-cell comes to contain only one of each kind of element: but he justified the validity of this assumption by putting it to a crucial test. His analysis was a wonderful feat of reasoning. He verified his reasoning by the recognized experimental procedure of science.

As a matter of fact it would not have been possible in Mendel's time to give an objective demonstration of the basic mechanism involved in the separation of the hereditary elements in the germ-cells. The preparation for this demonstration took all the thirty-five years between Mendel's paper in 1865 and 1900. It is here that the names of the most prominent European cytologists stand out as the discoverers of the rôle of the chromosomes in the maturation of the germ-cells. It is largely a result of their work that it was possible in 1902 to relate the well-known cytological evidence to Mendel's laws. So much in retrospect.

The most significant additions that have been made to Mendel's two laws may be called linkage and crossing over. In 1906 Bateson and Punnett reported a two-factor case in sweet peas that did not give the expected ratio for two pairs of characters entering the cross at the same time.

By 1911 two genes had been found in Drosophila that gave sex-linked inheritance. It had earlier been shown that such genes lie in the X-chromosomes. Ratios were found in the second generation that did not conform to Mendel's second law when these two pairs of characters are present, and the suggestion was made that the ratios in such cases could be explained on the basis of interchange between the two X-chromosomes in the female. It was also pointed out that the further apart the genes for such characters happen to lie in the chromosome, the greater the chance for interchange to take place. This would give the approximate location of the genes with respect to other genes. By further extension and clarification of this idea it became possible, as more evidence accumulated, to demonstrate that the genes lie in a single line in each chromosome.

Two years previously (1909) a Belgian investigator, Janssens, had described a phenomenon in the conjugating chromosomes of a salamander, Batracoseps, which he interpreted to mean that interchanges take place between homologous chromosomes. This he called chiasmatypie—a phenomenon that has occupied the attention of cytologists down to the present day. Janssens' observations were destined shortly to supply an objective support to the demonstration of genetic interchange between linked genes carried in the sex chromosomes of the female Drosophila.

To-day we arrange the genes in a chart or map, Fig. 1. The numbers attached express the distance of each gene from some arbitrary point taken as zero. These numbers make it possible to foretell how any new character that may appear will be inherited with respect to all other characters, as soon as its crossing over value with respect to any other two characters is determined. This ability to predict would in itself justify the construction of such maps, even if there were no other facts concerning the location of the genes; but there is to-day direct evidence in support of the view that genes lie in a serial order in the chromosomes.

What are the Genes?

What is the nature of the elements of heredity that Mendel postulated as purely theoretical units? What are genes? Now that we locate them in the chromosomes are we justified in regarding them as material units; as chemical bodies of a higher order than molecules?

Frankly, these are questions with which the working geneticist has not much concern himself, except now and then to speculate as to the nature of the postulated elements. There is no consensus of opinion amongst geneticists as to what the genes are—whether they are real or purely fictitious—because at the level at which the genetic experiments lie it does not make the slightest difference whether the gene is a hypothetical unit or whether the gene is a material particle. In either case the unit is associated with a specific chromosome, and can be localized there

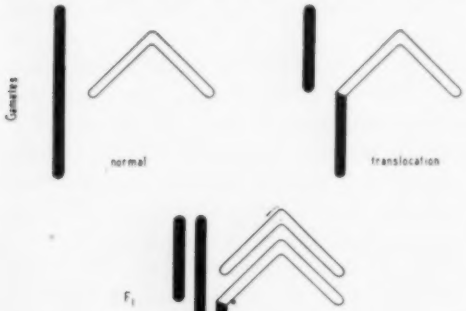


FIG. 2. DIAGRAM TO ILLUSTRATE THE CASE WHEN A PIECE OF ONE CHROMOSOME (BLACK) HAS BEEN TRANSLOCATED TO ANOTHER CHROMOSOME (WHITE). IN THE LOWER PART OF THE FIGURE THE METHOD OF CONJUGATION OF THESE CHROMOSOMES IS SHOWN.

by purely genetic analysis. Hence, if the gene is a material unit, it is a piece of a chromosome; if it is a fictitious unit, it must be referred to a definite location in a chromosome—the same place as on the other hypothesis. Therefore, it makes no difference in the actual work in genetics which point of view is taken.

Between the characters that are used by the geneticist and the genes that the theory postulates lies the whole field of embryonic development, where the properties implicit in the genes become explicit in the protoplasm of the cells. Here we appear to approach a physiological problem, but one that is new and strange to the classical physiology of the schools.

We ascribe certain general properties to the genes, in part from genetic evidence and in part from microscopical observations. These properties we may next consider.

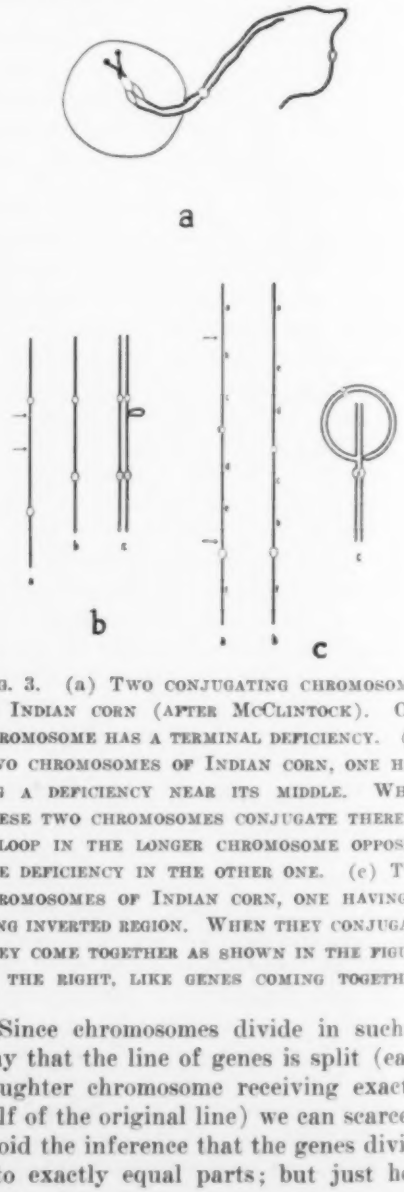


FIG. 3. (a) TWO CONJUGATING CHROMOSOMES OF INDIAN CORN (AFTER MCCLINTOCK). ONE CHROMOSOME HAS A TERMINAL DEFICIENCY. (b) TWO CHROMOSOMES OF INDIAN CORN, ONE HAVING A DEFICIENCY NEAR ITS MIDDLE. WHEN THESE TWO CHROMOSOMES CONJUGATE THERE IS A LOOP IN THE LONGER CHROMOSOME OPPOSITE THE DEFICIENCY IN THE OTHER ONE. (c) TWO CHROMOSOMES OF INDIAN CORN, ONE HAVING A LONG INVERTED REGION. WHEN THEY CONJUGATE THEY COME TOGETHER AS SHOWN IN THE FIGURE TO THE RIGHT, LIKE GENES COMING TOGETHER.

Since chromosomes divide in such a way that the line of genes is split (each daughter chromosome receiving exactly half of the original line) we can scarcely avoid the inference that the genes divide into exactly equal parts; but just how

this takes place is not known. The analogy of cell-division creates a presumption that the gene divides in the same way, but we should not forget that the relatively gross process involved in cell-division may seem quite inadequate to cover the refined separation of the gene into equal halves. As we do not know of any comparable division phenomena in organic molecules, we must also be careful in ascribing a simple molecular constitution to the gene. On the other hand, the elaborate chains of molecules built up in organic material may give us, some day, a better opportunity to picture the molecular or aggregate structure of the gene and furnish a clue concerning its mode of division.

Since by infinite subdivisions the genes do not diminish in size or alter as to their properties, they must, in some sense, compensate by growing between successive divisions. We might call this property autocatalysis, but, since we do not know how the gene grows, it is somewhat hazardous to assume that its property of growth after division is the same process that the chemist calls autocatalytic. The comparison is at present too vague to be reliable.

The relative stability of the gene is an inference from genetic evidence. For thousands—perhaps many millions—of subdivisions of its material it remains constant. Nevertheless, on rare occasions, it may change. We call this change a *mutation*, following de Vries' terminology. The point to emphasize here is that the mutated gene retains, in the great majority of cases studied, the property of growth and division, and more important still the property of stability. It is, however, not necessary to assume, either for the original genes or for the mutated genes, that they are all equally stable. In fact, there is a good deal of evidence for the view that some genes mutate oftener than others, and in a few cases the phenomenon is not infrequent, both in the germ-cells and in somatic tissues. Here the significant fact is that these repetitional changes are in definite and specific directions.

The constancy of position of genes with respect to other genes in linear order in the chromosomes is deducible, both from genetic evidence and from cytological observations. Whether the relative position is no more than a *historical accident* or whether it is due to some relation between each gene and its neighbors can not be definitely stated. But the evidence from the dislocation of a fragment of the chromosome and its reattachment to another one indicates that accident rather than mutual interaction has determined their present location: for, when a piece of one chromosome becomes attached to the end of a chain of genes of another chromosome or when a section of a chromosome becomes inverted, the genes in the new position hold as fast together as they do in the normal chromosome.

There is one point of great interest. So far as we can judge from the action of mutated genes, the kind of effect produced has as a rule no relation to location of the gene in the chromosome. A gene may produce its chief effect on the eye-color, while one nearby may affect the wing-structure, and a third, in the same region, the fertility of the male or of the female. Moreover, genes in different chromosomes may produce almost identical effects on the same organs. One may say, then, that the position of the genes in the hereditary material is inconsequential in relation to the effects that they produce. This leads to a consideration which is more directly significant for the physiology of development.

In the earlier days of genetics it was customary to speak of unit characters in heredity, because certain contrasted characters, rather clearly defined, furnished the data for the Mendelian ratios.

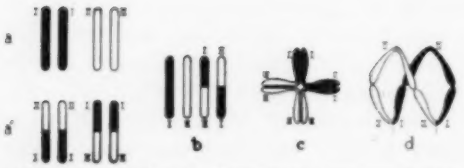


FIG. 4. DIAGRAM OF OENOTHERA CHROMOSOMES ILLUSTRATING THE CONFIGURATION OF CHROMOSOMES (c AND d) WHEN THERE HAS BEEN AN EXCHANGE BETWEEN DIFFERENT CHROMOSOMES AS INDICATED IN THE FIGURE BY THE BLACK AND WHITE. IN a AND a' AN EXCHANGE BETWEEN CHROMOSOMES I AND II IS SHOWN. IN b THE CHROMOSOME GROUP IS DRAWN, IN WHICH THERE ARE TWO INTERCHANGED CHROMOSOMES AND TWO WHOLE CHROMOSOMES. IN c THE COMING TOGETHER OF THESE FOUR CHROMOSOMES IS SHOWN, AND IN d THE RESULTS OF THE OPENING OUT OF THIS CROSS INTO A TWISTED RING. CHROMOSOME PAIRS, THAT CAME IN TOGETHER, PASS TO OPPOSITE POLES.

Certain students of genetics inferred that the Mendelian units responsible for the selected character were genes producing only a single effect. This was careless logic. It took a good deal of hammering to get rid of this erroneous idea. As facts accumulated it became evident that each gene produces not a single effect, but in some cases a multitude of effects on the characters of the individual. It is true that in most genetic work only one of these character-effects is selected for study—the one that is most sharply defined and separable from its contrasted character—but in most cases minor differences also are recognizable that are just as much the product of the same gene as is the major effect. In fact, the major difference selected for classification of the contrasted character-pairs may be of small importance for the welfare of the individual, while some of the concomitant effects may be of vital importance for the economy of the individual, affecting its vitality, its length of life or its fertility. I need not dwell at length on these relations because they are recognized to-day by all geneticists. It is important, nevertheless, to take cognizance of them, because the whole problem of the physiology of development is involved.

The coming together of the chromosomes at the maturation division, and their subsequent movement apart to opposite poles of the meiotic figure, insures the regular distribution of one set of chromosomes to each daughter-cell and the fulfilment of Mendel's second law. These movements have the appearance of physical events. Cytologists speak of

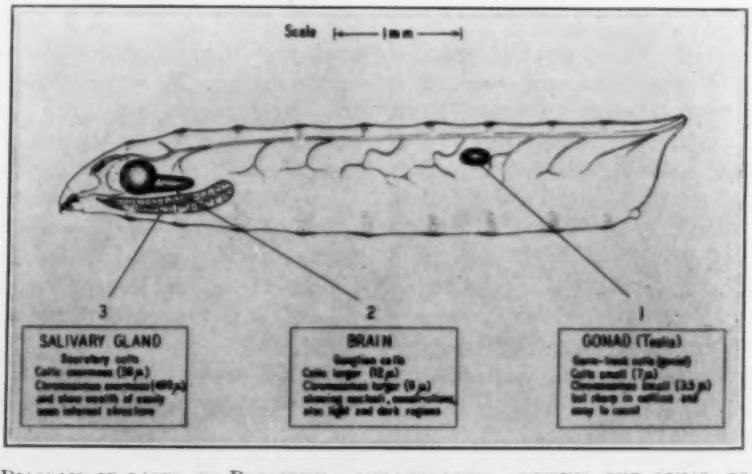


FIG. 5. DIAGRAM OF LARVA OF DROSOPHILA MELANOGASTER SHOWING THE GONAD, BRAIN AND ONE OF THE SALIVARY GLANDS.

these two phenomena as *attraction* and *repulsion* of the members of individual chromosomes, but we have no knowledge of the kind of physical processes involved. The terms attraction and repulsion are purely descriptive, and mean no more at present than that like chromosomes come together and later separate.

In earlier times, when the constitution of the chromosomes was not known, it was supposed that the chromosomes come together at random in pairs. There was the implication that any two chromosomes may mate. The comparison with conjugation of male and female protozoon, or egg and sperm-cell, was obvious, and since in all diploid cells one member of each pair of chromosomes has come from the father and one from the mother, it must have seemed that somehow maleness and femaleness are involved in the conjugation of the chromosomes also. But to-day we have abundant evidence to prove that this idea is entirely erroneous, since there are cases where both chromosomes that conjugate have come from the female, and even where both have been sister strands of the same chromosome.

Recent genetic analysis shows not only that the conjugating chromosomes are like chromosomes, *i.e.*, chains of the same genes, but also that very exact process is involved. The genes come together, point for point, unless some physical obstacle prevents. The last few years have furnished some beautiful illustrations showing that it is genes rather than whole chromosomes that come to lie side by side when the chromosomes come together. For example, occasionally a chromosome may have a piece broken off (Fig. 2, above) which becomes attached to another chromosome. A new linkage group is thus established. When conjugation takes place this piece has no corresponding piece in the sister chromosome. It has been shown (Fig. 2) that it then conjugates with that part of the parental chromosomes from which it came.

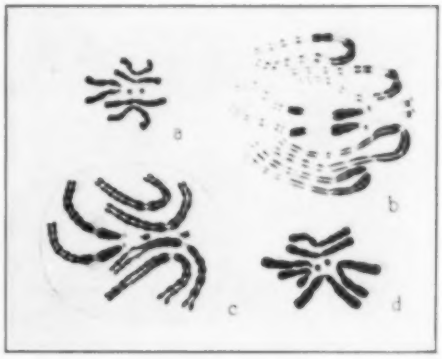
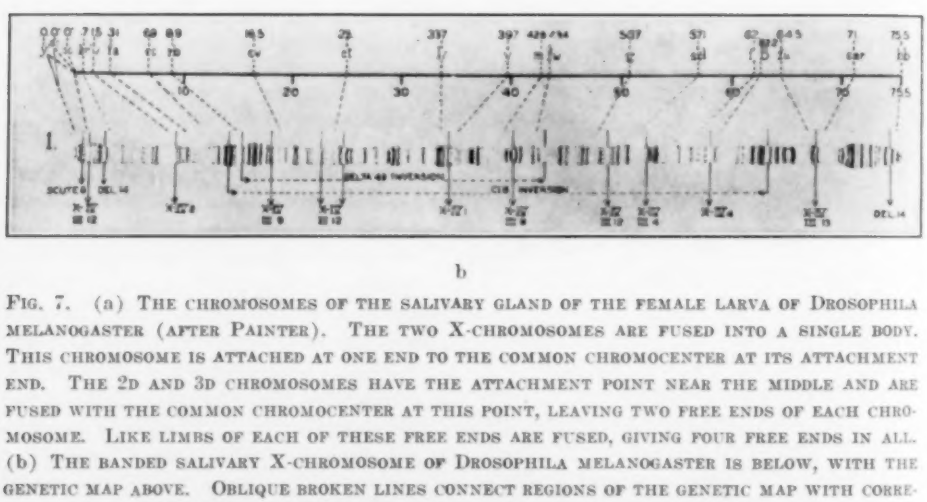


FIG. 6. THE RELATIVE SIZES OF THE CHROMOSOMES IN THE CELLS OF THE GONAD (a), OF THE GIANT GANGLION CELLS OF THE BRAIN (d), AND OF THE PROPHASE STAGE OF THE LATTER (b, c). IN a, A METAPHASE PLATE FROM THE GONAD IS SHOWN. IN b, A PROPHASE STAGE FROM A GANGLION CELL SHOWING THE BLACK (HEAVILY STAINED) INERT REGIONS OF THE CHROMOSOMES AND THE FAINTLY STAINED REGIONS CARRYING MOST OF THE GENES, ACCORDING TO HEITZ. IN c THE LATE PROPHASE OF THE SAME TYPE OF CELL IS SHOWN INTERMEDIATE BETWEEN b AND d. THE GENETIC REGION IS NOW STAINED. IN d (MALE) THE METAPHASE OF A GANGLION CELL HAS CHROMOSOMES LARGER THAN THOSE OF THE GONAD CELLS AS SHOWN IN a.

When a chromosome has lost one end, it conjugates with its mate only in part (Fig. 3a), *i.e.*, where like genes are present. When a chromosome has lost a small region, somewhere along its length, so that it is shorter than the original chromosome, the larger chromosome shows a loop which is opposite the region of deficiency in the shorter chromosome as shown in Fig. 3b. Thus like genes, or corresponding loci, are enabled to come together through the rest of the chromosome. More remarkable still is the case where the middle region of a chromosome has become turned around (inversion). When such a chromosome is brought together with its normal homologue, as shown in Fig. 3c, like regions come to-

a



b

FIG. 7. (a) THE CHROMOSOMES OF THE SALIVARY GLAND OF THE FEMALE LARVA OF DROSOPHILA MELANOGASTER (AFTER PAINTER). THE TWO X-CHROMOSOMES ARE FUSED INTO A SINGLE BODY. THIS CHROMOSOME IS ATTACHED AT ONE END TO THE COMMON CHROMOCENTER AT ITS ATTACHMENT END. THE 2D AND 3D CHROMOSOMES HAVE THE ATTACHMENT POINT NEAR THE MIDDLE AND ARE FUSED WITH THE COMMON CHROMOCENTER AT THIS POINT, LEAVING TWO FREE ENDS OF EACH CHROMOSOME. LIKE LIMBS OF EACH OF THESE FREE ENDS ARE FUSED, GIVING FOUR FREE ENDS IN ALL. (b) THE BANDED SALIVARY X-CHROMOSOME OF DROSOPHILA MELANOGASTER IS BELOW, WITH THE GENETIC MAP ABOVE. OBLIQUE BROKEN LINES CONNECT REGIONS OF THE GENETIC MAP WITH CORRESPONDING OR HOMOLOGOUS REGIONS OF THE SALIVARY CHROMOSOME.

gether by the inverted piece reversing itself, so to speak, so that like genes come together as shown to the right in Fig. 3c. In this same connection the conjugation of the chromosomes in species of Oenothera (Fig. 4) furnish beautiful examples of the way in which like series of genes find each other, even when halves of different chromosomes have been interchanged.

The very recent work of Heitz, Painter and Bridges has brought to light some astonishing evidence relating to the constitution of the chromosomes in the salivary glands of Drosophila, Figs. 5–10.

The nuclei of the cells of the salivary glands of the old larvae are very large and their contained chromosomes may be 70 to 150 times as long as those of the ordinary chromosomes in process of division. Heitz has shown that there are regions of some of the chromosomes of the ganglion cells—more especially of the X and the Y chromosomes—that stain deeply, and other regions faintly (Fig. 6) and that these regions cor-

respond to regions of the genetic map that do not and do contain genes. Painter has made the further important contribution that the series of bands of the salivary chromosomes can be homologized with the genetically known series of genes of the linkage maps (Fig. 7, a, b), and that the empty regions of the X and Y do not have the banded structure. He has further shown that when a part of the linkage map is reversed the sequence of the bands is also reversed; that when pieces are translocated they can be identified by characteristic bands: and that when pieces of linked genes are lost there is a corresponding loss of bands. Bridges has carried the analysis further by an intensive study of regions of particular chromosomes, and has shown a close agreement between bands and gene-location. With improved methods he has identified twice as many bands, thus making a more complete analysis of the relation of bands and gene-location. Thus, whether or not the bands are the actual genes, the evidence is clear in showing a remarkable agreement between the location of genes and the location of corresponding bands. The analysis of the banded structure has confirmed the genetic evidence, showing that when certain alterations of the order of the genes takes place there is a corresponding change in the sequence of the bands which holds for the finest details of the bands.

The number of chromosomes in the salivary nuclei is half that of the full number (as reported by Heitz) which Painter interprets as due to homologous chromosomes conjugating (Fig. 7a). Moreover, the bands in each of the component halves show an identical sequence which is strikingly evident when the halves are not closely apposed. It has been suggested by Bridges and by Koltzoff that homologous chromosomes have not only united, but that they have each divided two or three times, giving in some cases as many as 16 or 32 strands (Fig. 8). The bands may then be said to be composed each of 16 or 32 genes; or, if this identification of the bands as genes is questioned in so far as the genes are concerned, the bands are multiples of some kind of unit of which the chromosomes are composed.

A few examples may serve to illustrate

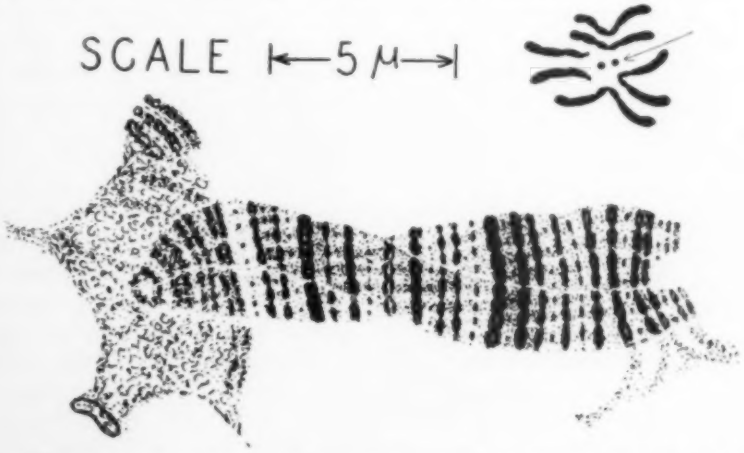


FIG. 8. ABOVE TO RIGHT THE FOUR PAIRS OF CHROMOSOMES OF DROSOPHILA IN THE METAPHASE STAGE FROM A CELL OF THE OVARY. THE TWO SMALLEST CHROMOSOMES ARE IN THE MIDDLE OF THE GROUP. THE SAME CHROMOSOMES FROM THE SALIVARY GLAND ARE DRAWN BELOW TO THE SAME SCALE (AFTER BRIDGES FROM THE JOURNAL OF HEREDITY).

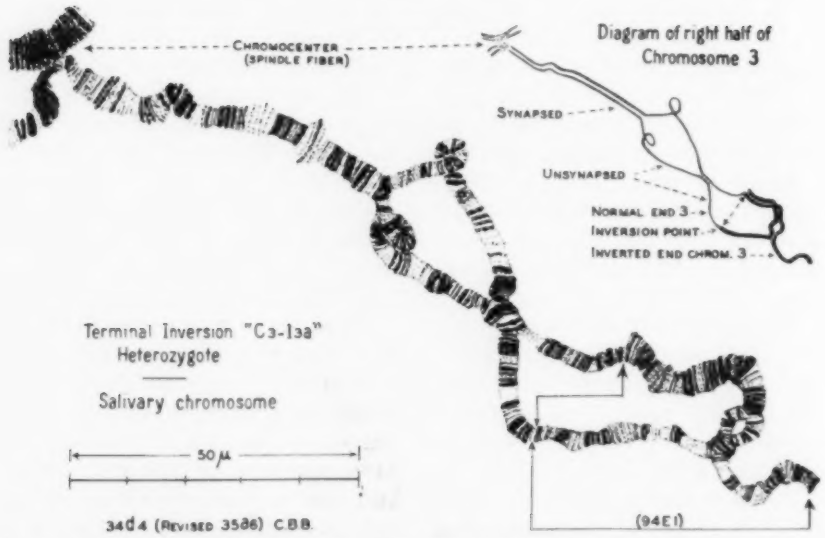


FIG. 9. SALIVARY GLAND PREPARATION OF RIGHT ARM OF THE THIRD CHROMOSOME, ILLUSTRATING A TERMINAL INVERSION IN ONE OF THE TWO COMPONENTS. THE TWO COMPONENTS ARE FUSED TOGETHER THROUGHOUT PART OF THEIR LENGTH AND ARE SEPARATE IN OTHER PARTS AS SHOWN IN THE SMALL DIAGRAM ABOVE AND TO RIGHT. THE TERMINAL INVERSION CONJUGATES WITH THE NON-INVERTED END BY TURNING BACK, AS PROVEN BY THE SEQUENCE OF THE BANDS. (AFTER BRIDGES.)

the way in which the banded chromosomes confirm the genetic conclusions as to occasional changes that have taken place in the serial order of the genes. In Fig. 9 the right half of chromosome 3 from the salivary gland is represented. In part the two components are fused, in part are separate. In the lower part of the figure a reversed piece of one component is present (terminal inversion). Like bands conjugate with like and, as shown in the smaller diagram above, Fig. 9, this is made possible by the end of one component turning back on itself. In Fig. 10 is drawn a short region of chromosome 2. One component has a deficiency for certain genes; the opposite normal chromosome forms a bulge in the region of the deficiency, allowing like bands to come together above and below the deficiency level.

THE PHYSIOLOGICAL PROPERTIES OF THE GENES

If, as is generally implied in genetic work (although not often explicitly stated), all the genes are active all the time; and if the characters of the individual are determined by the genes, then why are not all the cells of the body exactly alike?

The same paradox appears when we turn to the development of the egg into an embryo. The egg appears to be an unspecialized cell, destined to undergo a prescribed and known series of changes leading to the differentiation of organs and tissues. At every division of the egg, the chromosomes split lengthwise into exactly equivalent halves. Every cell comes to contain the same kinds of genes. Why, then, is it that some cells become muscle cells, some nerve cells and others remain reproductive cells?

The answer to these questions seemed relatively simple at the end of the last century. The protoplasm of the egg is visibly different at different levels. The fate of the cells in each region is determined, it was said, by the differences in different protoplasmic regions of the egg.

Such a view is consistent with the idea

that the genes are all acting; the initial stages of development being the outcome of a reaction between the identical output of the genes and the different regions of the egg. This seemed to give a satisfactory *picture* of development, even if it did not give us a *scientific explanation* of the kind of reactions taking place.

But there is an alternative view that can not be ignored. It is conceivable that different batteries of genes come into action one after the other, as the embryo passes through its stages of development. This sequence might be assumed to be an automatic property of the chain of genes. Such an assumption would, without proof, beg the whole question of embryonic development, and could not be regarded as a satisfactory solution. But it might be that in different regions of the egg there is a reaction between the kind of protoplasm present in those regions and specific genes in the nuclei; certain genes being more affected in one region of the egg, other genes in other regions. Such a view might give also a purely formal hypothesis to account for the differentiation of the cells of the embryo. The initial steps would be given in the regional constitution of the egg.

The first responsive output of the genes would then be supposed to affect the protoplasm of the cells in which they lie. The changed protoplasm would now act reciprocally on the genes, bringing into activity additional or other batteries of genes. If true this would give a pleasing picture of the developmental process. A variation of this view would be to assume that the product of one set of genes is gradually in time overtaken and nullified or changed by the slower development of the output of other genes, as Goldschmidt, for example, has postulated for the sex-genes. In the last case the theory is dealing with the development of hybrid embryos whose sex-genes are assumed to have different rates of activity.

A third view may also be permissible. Instead of all the genes acting in the same way all the time or instead of certain kinds of genes coming successively into action, we might postulate that the kind of activity of all the genes is changed in response to the kind of protoplasm in which they lie. This interpretation may seem less forced than the others, and in better accord with the functional activity of the adult organ-systems.

We must wait until experiments can be devised that will help us to discriminate between these several possibilities. In fact, geneticists all over the world are to-day trying to find methods that will help to determine the relation of genes to embryonic and adult characters. The problem (or problems) is being approached both from a study of chemical

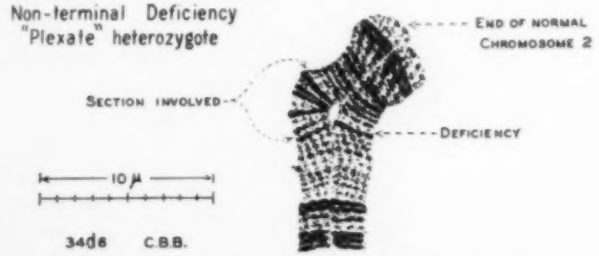


FIG. 10. SALIVARY GLAND PREPARATION SHOWING A PART OF CHROMOSOME 2. THERE IS A DEFICIENCY IN ONE OF THE TWO CONJUGANTS. AT THE LEVEL OF THE DEFICIENCY THE OTHER COMPONENT IS BENT OUTWARDS, SO THAT ABOVE AND BELOW THIS LEVEL LIKE BANDS MEET. THIS FIGURE ALSO SHOWS THAT THE SALIVARY CHROMOSOMES ARE MADE UP OF 16 STRANDS, THE 16 ELEMENTS OF WHICH FUSE TOGETHER TO MAKE EACH OF THE CROSS BANDS. (AFTER BRIDGES.)

changes that take place near the final steps in organ formation, especially in the development of pigments, and from a study of the early differentiation of the cell-groups of the embryo.

We have also come to realize that the problem of development is not as simple as I have so far assumed to be the case, for it depends, not only on independent cell differentiation of individual cells, but also on interactions between cells, both in the early stages of development and on the action of hormones on the adult organ systems. At the end of the last century, when experimental embryology greatly flourished, some of the most thoughtful students of embryology laid emphasis on the importance of the interaction of the parts on each other, in contrast to the theories of Roux and Weismann that attempted to explain development as a progressive series of events that are the outcome of self-differentiating processes or, as we would say today, by the sorting out of genes during the cleavage of the egg. At that time there was almost no experimental evidence as to the nature of the postulated interaction of the cells. The idea was a generalization rather than an experimentally determined conclusion, and, unfortunately, took a metaphysical turn.

To-day this has changed, and owing mainly to the extensive experiments of the Spemann school of Germany, and to the brilliant results of Hörstadius of Stockholm, we have positive evidence of the far-reaching importance of interactions between the cells of different regions of the developing egg. This implies that original differences are already present, either in the undivided egg or in the early formed cells of different regions. From the point of view under consideration results of this kind are of interest because they bring up once more, in a slightly different form, the problem as to whether the organizer acts first on the protoplasm of the neighboring region with which it comes in contact, and through the protoplasm of the cells on the genes; or whether the influence is more directly on the genes. In either case the problem under discussion remains exactly where it was before. The conception of an organizer has not as yet helped to solve the more fundamental relation between genes and differentiation, although it certainly marks an important step forward in our understanding of embryonic development.

Genetics and Medicine

That man inherits his characters in the same way as do other animals there can be no doubt. The medical literature contains hundreds of family pedigrees, in which certain characters, usually malformations, appear more frequently than in the general population. Most of these are structural defects; a few are physiological traits (such as haemophilia); others are psychopathic. Enough is already known to show that they follow genetic principles.

Man is a poor breeder—hence many of these family pedigrees are too meager to furnish good material for genetic analysis. When an attempt is made to combine pedigrees from different sources in order to insure sufficient data, the question of correct diagnosis sometimes presents serious difficulties, especially in the older materials; but with the very great advances that have been made in medical diagnosis in recent years this difficulty will certainly be less serious in the future.

The most important contribution to medicine that genetics has made is, in my opinion, intellectual. I do not mean to imply that the practical applications are unimportant, and I shall in a moment point out some of the more obvious connections, but the whole subject of human heredity in the past (and even at the present time in uninformed quarters) has been so vague and tainted by myths

and superstitions that a scientific understanding of the subject is an achievement of the first order. Owing to genetic knowledge medicine is to-day emancipated from the superstition of the inheritance of maternal impressions: it is free from the myth of the transmission of acquired characters, and in time the medical man will absorb the genetic meaning of the rôle of external environment in the coming to expression of genetic characters.

The importance of this relation will be seen when it is recalled that the germplasm or, as we say, the genic composition of man is a very complex mixture—much more so than that of most other animals, because in very recent times there has been a great amalgamation of many different races owing to the extensive migration of the human animal, and also because man's social institutions help to keep alive defective types of many kinds that would be eliminated in wild species through competition. Medicine has been, in fact, largely instrumental in devising means for the preservation of weak types of individuals, and in the near future medical men will, I suggest, often be asked for advice as to how to get rid of this increasing load of defectives. Possibly the doctor may then want to call in his genetic friends for consultation! The point I want to make clear is that the complexity of the genic composition of man makes it somewhat hazardous to apply only the simpler rules of Mendelian inheritance; for, the development of many inherited characters depends both on the presence of modifying factors and on the external environment for their expression.

I have already pointed out that the gene generally produces more than one visible effect on the individual, and that there may be also many invisible effects of the same gene. In cases where a condition of susceptibility to certain diseases is present, it may be that a careful scrutiny will detect some minor visible effects produced by the same gene. As yet our knowledge on this score is inadequate, but it is a promising field for further medical investigation. Even the phenomenon of linkage may some day be helpful in diagnosis. It is true there are known as yet in man no certain cases of linkage, but there can be little doubt that there will in time be discovered hundreds of linkages and some of these, we may anticipate, will tie together visible and invisible hereditary characteristics. I am aware, of course, of the ancient attempts to identify certain gross physical human types—the bilious, the lymphatic, the nervous and the sanguine dispositions and of more modern attempts to classify human beings into the cerebral, respiratory, digestive and muscular, or, more briefly, into asthenics and pycnics. Some of these types are supposed to be more susceptible to certain ailments or diseases than are other types, which in turn have their own constitutional characteristics. These well-intended efforts are, however, so far in advance of our genetic information that the geneticist may be excused if he refuses to discuss them seriously.

In medical practice the physician is often called upon for advice as to the suitability of certain marriages where a hereditary taint is present in the ancestry. He is often called upon to decide as to the risk of transmitting certain abnormalities that have appeared in the first-born child. Here genetics will, I think, be increasingly helpful in making known the risk incurred and in distinguishing between environmental and hereditary traits.

Again, a knowledge of the laws of transmission of hereditary characters may sometimes give information that may be helpful in the diagnosis of certain diseases in their incipient stages. If, for example, certain stigmata appear,

whose diagnosis is uncertain, an examination of the family pedigree of the individual may help materially in judging as to the probability of the diagnosis.

I need scarcely point out those legal questions concerning the paternity of an illegitimate child. In such cases a knowledge of the inheritance of blood groups, about which we now have very exact genetic information, may often furnish the needed information.

Geneticists can now produce, by suitable breeding, strains of populations of animals and plants that are free from certain hereditary defects; and they can also produce, by breeding, plant populations that are resistant or immune to certain diseases. In man it is not desirable, in practice, to attempt to do this, except in so far as here and there a hereditary defective may be discouraged from breeding. The same end is accomplished by the discovery and removal of the external causes of the disease (as in the case of yellow fever and malaria) rather than by attempting to breed an immune race. Also, in another way the same purpose is attained in producing immunity by inoculation and by various serum treatments. The claims of a few enthusiasts that the human race can be entirely purified or renovated, at this later date, by proper breeding, have I think been greatly exaggerated. Rather must we look to medical research to discover remedial measures to insure better health and more happiness for mankind.

While it is true, as I have said, some little amelioration can be brought about by discouraging or preventing from propagating well-recognized hereditary defects (as has been done for a long time by confinement of the insane), nevertheless it is, I think, through public hygiene and protective measures of various kinds that we can more successfully cope with some of the evils that human flesh is heir to. Medical science will here take the lead—but I hope that genetics can at times offer a helping hand.

ACCELERATED EROSION

ITS EFFECTS ON SOIL AND WATER RESOURCES

By Dr. W. C. LOWDERMILK

VICE-DIRECTOR, SOIL EROSION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

IMMIGRANTS to the North American continent found a promised land fulfilling in its offerings the fondest imaginations of man. Neither to the sons of Abraham in Canaan nor to the sons of Han in Cathay were there offered such rewards for effort as the land of America held out to the eager explorers and colonists three centuries ago. It lay before their hopeful eyes rich in land, timber, game, fish and fur. So abundant were these good things that they were believed to be limitless and inexhaustible. This false concept has persisted in the thinking of the American people until to-day, long after limits in many areas have been reached. This concept has been responsible for a tardy realization of the need of wise use of natural resources for this generation and for those that follow.

Except in an insignificant way, the aborigines had done little to cultivate the soil or to change the pristine character of the land surface and its vegetation. The coverage of vegetation and the soils protected by it were responses to the long processes of soil and plant development under favorable climates. The streams bore oceanward the residue of precipitation that watered the land and nourished vast areas of vegetation. Rivers draining the regions covered with dense vegetation ran clear, except in high flood when channel erosion furnished the major burden of silt. This

THE BREAKDOWN OF SOILS IN MISSISSIPPI

CAUSED BY UNWISE USE OF LAND. THE UTILITY OF THESE FORMERLY PRODUCTIVE LANDS HAS BEEN DESTROYED PERMANENTLY FOR FIELD CROPS, AND WITH IT THE FINANCIAL AND SOCIAL SECURITY OF EXTENSIVE RURAL SECTIONS. SOME DAY WE SHALL BE BADLY IN NEED OF THESE LANDS. PRODIGALITY OF THIS NATURE CAN NOT BE JUSTIFIED.

A GULLY IN THE PIEDMONT OF THE ATLANTIC SLOPE

TYGER CREEK DRAINAGE, NEAR SPARTANBURG, SOUTH CAROLINA. THE ORIGINAL TOP-SOIL NORMALLY 12 TO 16 INCHES DEEP IN THIS REGION HAS BEEN PRACTICALLY WASHED AWAY BY SHEET EROSION. REMNANTS MAY BE SEEN ON THE EDGE OF THE GULLY. A HEAVY RED CLAY SUB-SOIL 3 TO 5 FEET DEEP OVERLIES A DEEP HIGHLY WEATHERED PARENT IGNEOUS MATERIAL WHICH CRUMBLES AND ERODES RAPIDLY ONCE THE TOUGH SUB-SOIL IS CUT THROUGH.

A MEANDERING GULLY

WHICH HAS ALREADY RUINED SEVERAL ACRES OF A FINE BLUEGRASS PASTURE, NEAR BETHANY, MO., AND IS STILL CUTTING.

channel erosion generated soil creep from vegetated slopes and in addition to solution served to sculpture and wear down the land with the leisure of geologic processes. Where comparatively rapid differential land uplift had occurred or within climatic zones too rigorous or too arid to support an unbroken cover of vegetation, storm waters carried substantial quantities of silt into streams. Processes proceeded in these cases at more rapid rates; streams ran muddy throughout most of the year, as deep soils honeycombed by the burrowing of insects and plant roots. Little surface soil wash occurred. Certainly the processes of erosion, which may be designated under these circumstances as geologic norms of erosion, had not proceeded at rates in excess of those of soil formation: For beneath the coverage of vegetation lay the nourishing soils of varying depths, the product of intricate processes of soil formation during thousands of years. This fact is of highest importance in considering problems

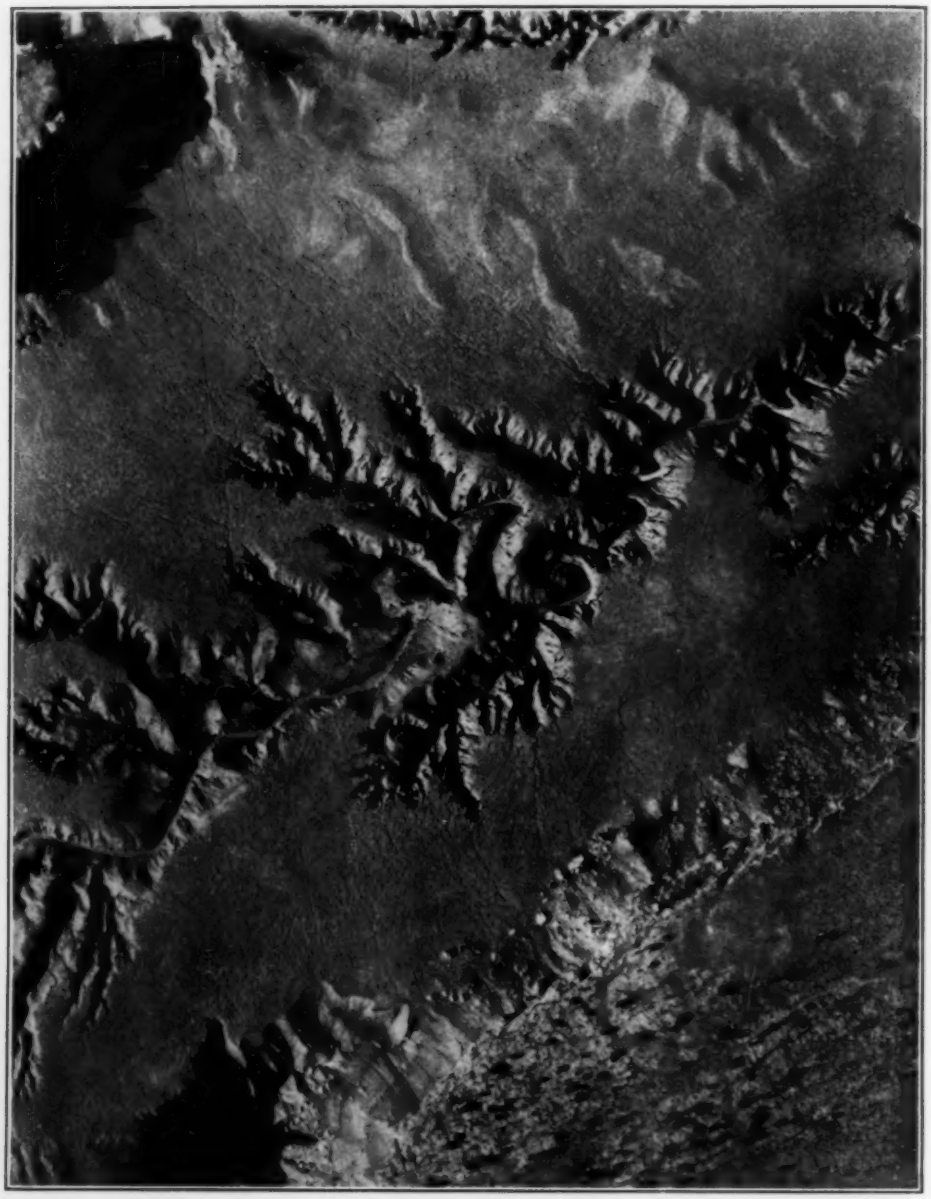
ARROYO EROSION IN NEW MEXICO

A VIEW OF A RAPIDLY ENLARGING GULLY ON ZUNI INDIAN RESERVATION SHOWING THE MANNER IN WHICH AN ALLUVIAL FILLED VALLEY IS BEING RE-EXCAVATED BY AN ARROYO. THE STAGE OF BASE LEVEL CUTTING HAS BEEN REACHED AND THE VALLEY FILL MATERIAL IS BEING EXCAVATED BY BANK CUTTING. MILLIONS OF ACRE FEET OF ALLUVIAL VALLEY MATERIAL IN WESTERN UPLAND VALLEYS IS THUS SUSCEPTIBLE TO EXCAVATION AND TRANSPORT INTO IRRIGATION RESERVOIRS. ACCELERATED CUTTING OF THESE ARROYOS MAY BE CHARGED TO THE CONCENTRATION OF RUNOFF INTO STREAMS OF HIGH VELOCITY, WHICH CUT LIKE RIP-SAWS INTO THE ALLUVIAL FILL. THE CONCENTRATION OF FLOW IS OCCASIONED BY BARING OF SLOPES BY OVERGRAZING, BY CATTLE TRAILS AND BY ROAD CONSTRUCTION WITHOUT DUE RESPECT TO THE SENSITIVE BALANCE BETWEEN DEPOSITION AND TRENCHING IN THIS REGION.

in the cases of the Missouri and Colorado.

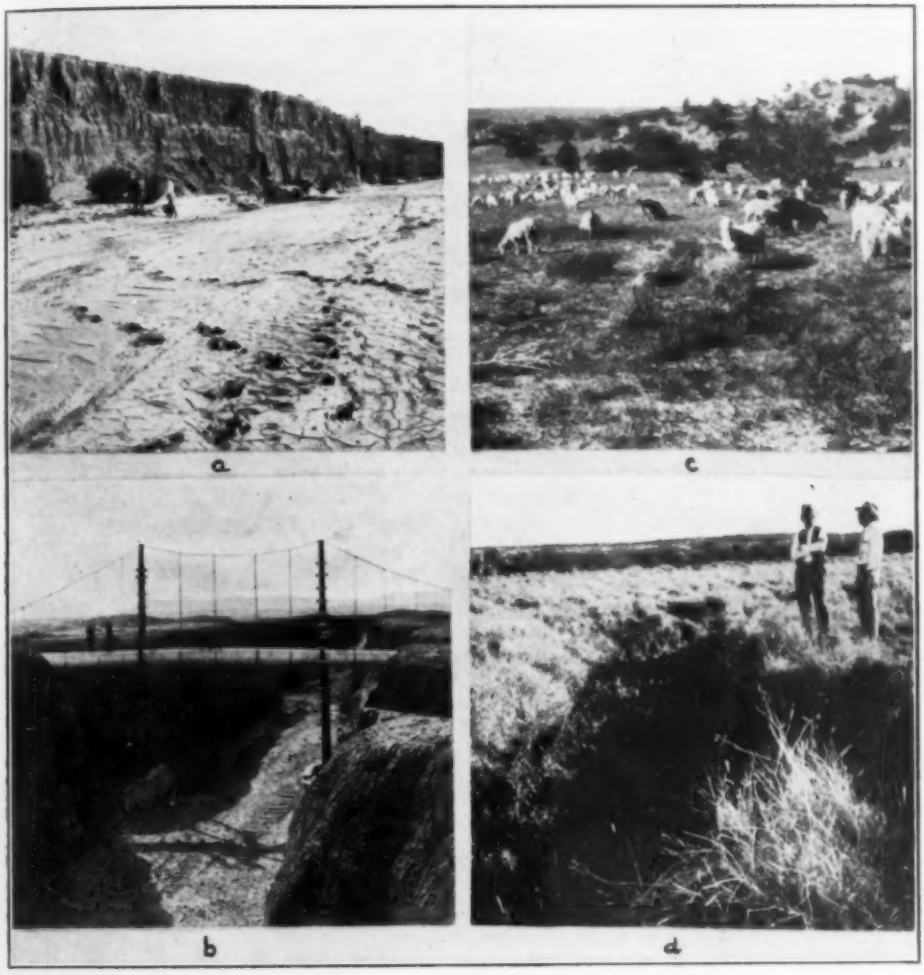
In the broad expanses of our country, from semi-tropical to boreal climates, from humid to arid conditions, there spread before the eager colonists an infinite variety of conditions. By far the larger area was completely covered by vegetation from grasses to dense forests. Such coverage had in the long period of interdependence of soil formation and vegetative succession protected surfaces of soils from rain wash, and favored the absorption of rain and melting snow by affecting the long-time planning in land use. Under native conditions erosion had not exceeded soil formation.

Into this pristine continent entered the eager colonists with a burst of energy that began a transformation of the earth's surface at a rate which probably had never before occurred in the earth's history, and with it the creation of a nation of fabulous wealth. There were reservoirs of population in Europe which supplied in a comparatively short time millions of vigorous people and their sons and daughters to clear away



AN OCTOPUS-LIKE GULLY

REACHING OUT WITH ITS TENTACLES TO DEVOUR THE VALLEY FILL OF ALLUVIUM IN ARIZONA, WHERE THE BALANCE BETWEEN DEPOSITION OF ALLUVIUM AND TRENCHING WITH GULLIES IS VERY SENSITIVE TO DISTURBANCES, SUCH AS OVERGRAZING. UNLESS SUCH CUTTING IS STOPPED THIS GULLY WILL REMOVE THE ALLUVIUM OF THIS VALLEY FILL AND MOVE IT DOWN THE DRAINAGE INTO IRRIGATION RESERVOIRS. THIS AREA IS HEAVILY OVERGRAZED BY SHEEP OF THE NAVAJO INDIANS.



EROSION IN THE SOUTHWEST

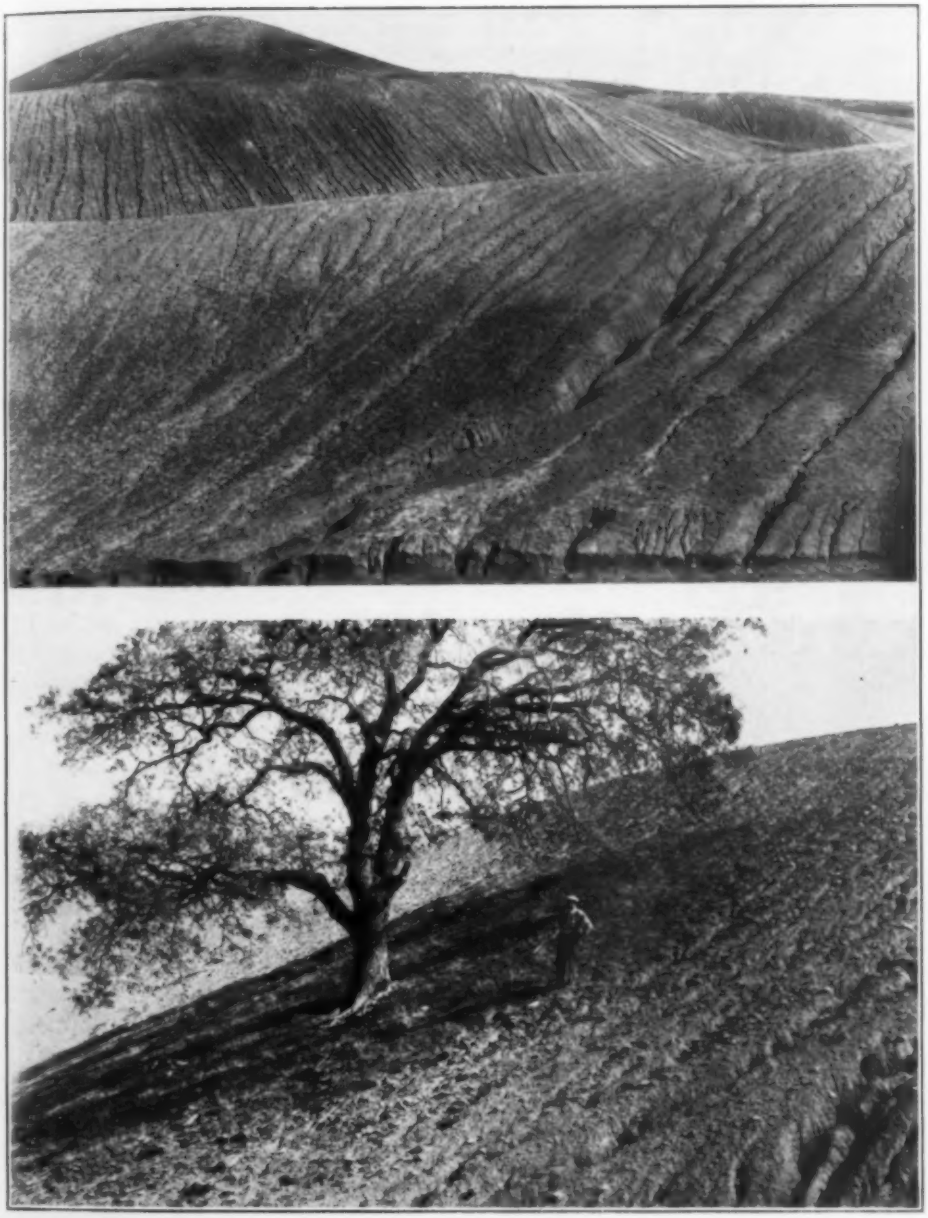
(a) The San Simon Wash. Some idea of the quantity of alluvium which has been washed out of this valley may be had when it is realized that in 1889 this valley had a flat floor level with the top of the bank. (b) Once the scene of a grassy flat which supplied hay and excellent grazing on the upper Gila River valley. The irrigation water now conducted in the suspended culvert flowed in an open ditch at this point 35 years ago. This great gully is cutting out rapidly and is feeding the San Carlos Reservoir with great quantities of silt to destroy storage capacity, in turn to jeopardize the irrigation project dependent upon it. (c) Sheep and goats may be useful and destructive, and in the end bring about conditions inducing quickened surficial runoff and accelerated erosion and gully trenching on western range lands. A herd on the Navajo country in Arizona. (d) A grassy flat, which represents the condition on alluvial valley floors in the Southwest when the white man came with his herds. Note that a gully has started as a result of accelerated run-off from surroundings.

the forests and to cultivate the soil at an astonishing rate in their westward march of agricultural occupation. It was no steady infiltration into undeveloped regions, but a rapid advance over a wide front by farmers and stockmen with their plows and herds. Frontiers were pushed farther and farther westward even to the Pacific shore by these sturdy folk with scarcely a thought for conservation or a planned use of these natural resources that lay before them to the horizon. It was the victorious occupation of an exultant invader. The advance was checked a little by the forests which required the hard work of felling and burning to clear the land. Advance was more rapid in the grasslands. The prairie sod was broken over vast areas, and next the short grass country of the great plains. Buffaloes were slaughtered by the thousands merely for their hides. There was no time to think of conservation, and waste marked the rapid occupation of the land. The habit of thought which the period of rapid occupation developed has persisted too long. The frontier has dissolved in the Pacific and reappears in the sustained and conservative use of the land now occupied.

Withal, it is only necessary here to call attention to the significant changes in rates of erosional processes occasioned by the clearing of vegetation and the breaking of the soil with the plow and the heavy consumption of the forage herbage by rapidly multiplying herds. Soils, which had been thoroughly protected through thousands of years of time by unbroken mantles of vegetation and had for this reason weathered to fine textures and high fertility, were suddenly exposed to the dash of torrential rains over extensive areas. There began under these conditions a rate of erosion which was accelerated far above the rate which had hitherto been obtained. The significant fact of this period of rapid agricultural occupation is that the rate of erosion exceeded and still does exceed the rate of soil formation over vast areas —a certain process of soil destruction. Top-soils have been literally washed away, leaving sub-soils exposed at the surface, such as is conspicuous over the entire Piedmont region of more than fifty million acres, as well as over numerous other regions of the country. Moreover, concentration of run-off has cut enormous gullies through top-soils and sub-soils into the underlying material often less stable than the soil above. So enormous has been the work of accelerated erosion as to reduce and destroy productivity of millions of acres of soils of densely populated regions of the United States within less than a century. The economic and social aspects of this transformation embody some of the most serious problems of the nation.

The acceleration of erosion in the east and in the south, in the north and in the west, has carried with it consequences of first importance in permanence of investments in the billions of dollars in navigation, hydroelectric power, municipal water supply and irrigation developments. Accelerated erosion has combined with an acceleration of superficial run-off from bared slopes to accentuate flood peaks and to augment the cutting power of stream flow. Still more significant is the transformation of fertile soils into troublesome silt and sediments. Products of soil wash and gully excavation have been carried by storm flows to be deposited in stream channels and in existing reservoirs. Shoaling of streams and rivers has followed large-scale erosion of upland soils. Particularly significant and important is the rapid rate of silting which is going on in reservoirs located on streams within critically eroding areas of the country. This applies to the East as well as to the West.

In the Piedmont region of the Atlantic Seaboard, many reservoirs impounded by dams constructed for the development of power have silted up to



WHAT HAPPENS WHEN A CLOUDBURST STRIKES AN OVERGRAZED AREA IN THE WEST—TCHACHAPI FLOOD OF 1932

ABOVE, FORMERLY GRASS-COVERED SLOPES RIDDLED WITH GULLIES IN A 7-INCH RAIN STORM. BELOW, A REMARKABLE EXAMPLE OF THE EFFECT OF A TREE AND ITS LITTER AND PROTECTED GRASS IN THE MIDST OF THE CLOUDBURST AREA. GULLIES WHICH STARTED ABOVE FANNED OUT ON THE GRASS AND LITTER COVER. AT NO POINT DID GULLIES CUT THROUGH THIS SURFACE.

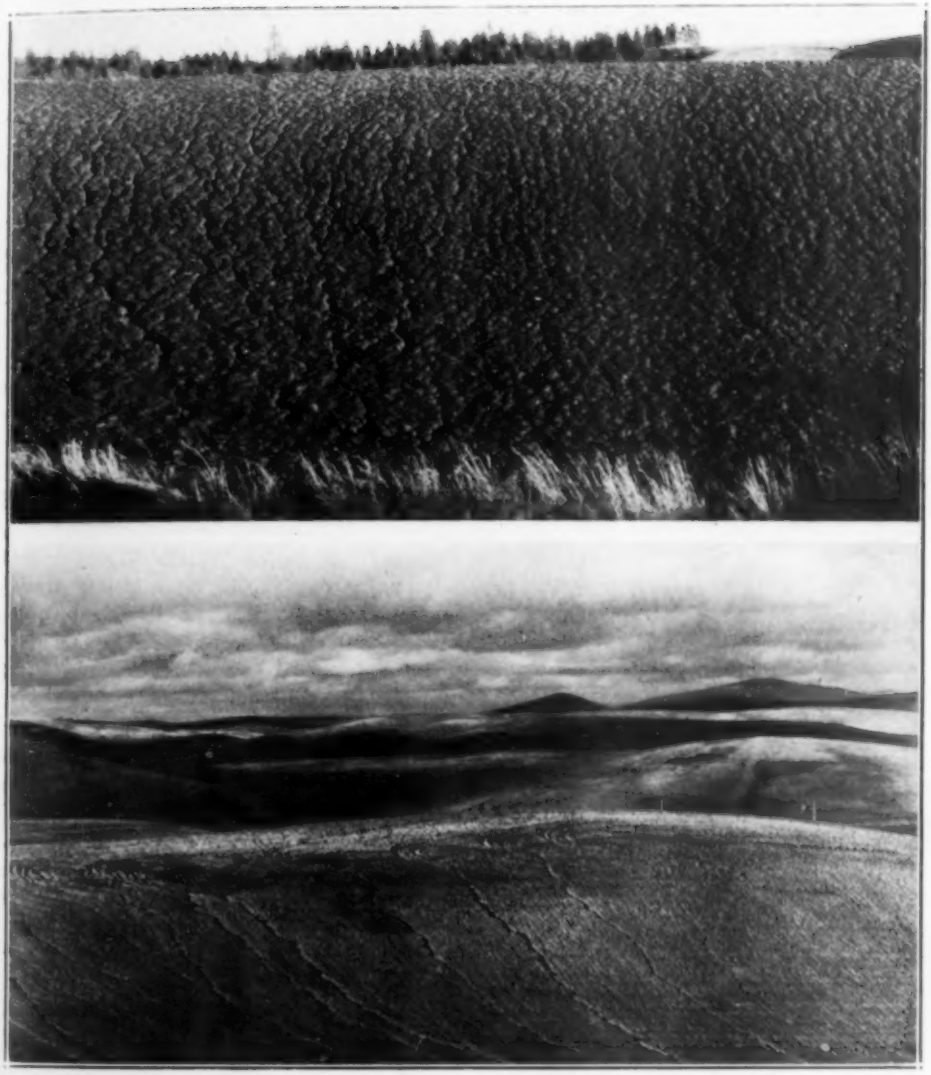
the very brim within the last 40 or 50 years. On the Deep River in North Carolina, 11 out of 13 such dams are reported to be entirely silted up. The reservoir at Oakdale near High Point, North Carolina, is now silted to the brim after 40 odd years and is a portentous example of the results of soil wastage on cultivated slopes within that drainage. On the other hand, the irrigated civilization of the West is doomed if the accelerated rate of silting in the irrigation reservoirs is not soon brought under adequate control. Hundreds of millions of dollars have gone into the construction of dams for power and for irrigation in the arid and semi-arid West. The Austin Dam in Texas has silted up to 85 per cent. of its capacity in 20 years. The Elephant Butte Reservoir of New Mexico with an original storage capacity of 2,638,860 acre feet supplies one of the largest irrigation projects of the West and is silting up at a disquieting rate. It was originally forecast to have a life of 233 years on the basis of silt studies of the Rio Grande River from 1897–1912, as reported by the *Reclamation Record*. After the completion of the Elephant Butte Dam in 1915, silt surveys have been regularly made in the reservoir. From 1915 to 1925 the average annual rate of silting was estimated at 20,000 acre feet, forecasting a life of 132 years; from 1926 to 1929, inclusive, 21,943 acre feet, forecasting a life of 110 years. Erosion of alluvial valleys above the reservoir is increasing yearly. But still more ominous is the fact that within approximately 60 years the storage capacity of this reservoir would equal the annual draft of water for the irrigated land. During dry years the lands will suffer a shortage of water, and from that time on irrigation under the Elephant Butte Reservoir will be a precarious enterprise.

These are samples of many other instances which ominously forecast financial losses, social insecurity and depopulation of regions dependent upon water stored in reservoirs. In the long view ahead, the situation is critical and calls for statesmanship in planning for coordinated uses of all the resources of water and land within these regions.

Conclusions that serious acceleration of erosion has taken place are not based upon field observation alone. They are founded upon experimental measurements at 12 erosion experiment stations, which have given quantitative values to the acceleration of erosion by processes of clearing for cultivation and by burning and overgrazing of native vegetation. Experimentally, the rate of superficial run-off from bared soils has been found to be from 3 to 40 times that from soils covered with unbroken vegetation and erosion many thousand fold that from slopes covered with vegetation. Measurements on the principal soil type of north-central Missouri within the drainage of the Missouri River have shown, for example, a loss of top-soil from corn land on an average slope of 8 per cent., equalling 67 tons per acre per annum, along with a superficial run-off of 26 per cent. of the total rainfall; whereas from the same type of soil thickly covered with alfalfa, the corresponding losses were 0.4 tons of soil per acre per annum, and with it 1.7 per cent. of the rainfall in run-off.

In approaching problems of coordinated use of waters, soils and vegetation on a long-time basis, the significance and implication of the acceleration of the processes of erosion must be taken into consideration and adequately met to safeguard and protect investments of billions of dollars and social security of millions of people.

The American people face two alternatives in this respect. One is to let continue the processes now destroying the productivity and utility of millions of acres of land and adding annually to a bankrupt domain which is becoming an increasing burden upon counties,



SHEET AND RILL EROSION IN THE PALOUSE REGION

DETAIL OF THE MANNER OF WORK OF SHEET AND RILL EROSION IN REMOVING TOP-SOIL FROM UNPROTECTED FIELDS. THIS IS SUICIDAL AGRICULTURE; FOR THE UTILITY OF CROPS OF THESE LANDS UNDER PRESENT PRACTICE IS BEING DESTROYED. THE SOIL EROSION SERVICE HAS DEVELOPED PRACTICES OF CULTIVATION, AND CROPPING AND WITHDRAWAL FROM CLEAN TILLED CROPS WHICH SAFEGUARDS THE UTILITY OF SUCH LANDS TO THE PRESENT AND FUTURE GENERATIONS.

states and the Federal Government. Such a way out is not pleasant to contemplate. The other alternative is to diagnose the situation, take full account of the significance and trend of destructive processes of soil wastage, acceleration of run-off and sedimentation of reservoirs, to relate these to all land use within drainage basins and to set up a program to control and reduce these processes to a rate as far as possible and practicable equal to the rates which existed when the white man found the country covered with unbroken vegetation. Agriculture under such rates of erosion would cease to be self-destructive, and would be founded on a physical base for sustained production.

Production of agricultural field crops necessary for the provisioning of our people requires the clearing of land. Such clearing accelerates the rate of surface soil wash above the rate under a cover of native vegetation. The acceleration varies widely, however, with soil type, slope, nature and distribution of rainfall, and especially with methods of cropping and cultivating the soil. A division line between sustained cropping and suicidal agriculture exists in each region and should be drawn in the interests of the present as well as future generations. It is important to establish such a division line between practicable cultural and cropping methods. This is a task of first order of importance which the Soil Erosion Service is undertaking, on a series of 40 large-scale demonstration areas throughout the nation, located in representative regions of serious soil wastage through erosion.

To accomplish this herculean task requires drastic measures. Large areas of steeper slopes of erosive soils within rainfall zones of torrential downpour must be withdrawn from cultivation and returned to perennial crops of grass or forests. Partial redistribution of population of these sections is indicated. In other regions and districts, use of great areas of grass lands must be controlled and supplemented by artificial means of erosion control. Each drainage area is a problem unto itself and must be specially studied to work out measures applicable to the problems existing therein.

Summary

The beneficial use of waters of the nation can not be considered apart from the processes of erosion within the drainages yielding that water. Where human occupation and use may accelerate erosion so as to damage interests of navigation, hydro-electric power, municipal supply and irrigation development, special attention to coordinated use of these resources is required. Each region has peculiarities unto itself in the interrelations of rainfall, topography, natural vegetation and the soil which has been thousands of years in formation. There is needed principally a classification or zoning of each drainage, to assign to those zones the methods of culture or of production or utilization of its resources which would prevent the ruinous acceleration of erosion and of stream flow and the maintenance of the beneficial use of water resources. Within such a project may be forecast a program of development whereby not only will sustained productivity of soils be assured, but erratic flood flows will be minimized or reduced and beneficial power and utilization of the water of the country preserved in the highest degree.

NATURE IN SIAMESE AND CAMBODIAN ART

By Dr. GORDON ALEXANDER

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ART is of double inspiration. It is the expression of the inner man at the same time that it depicts the external world. It is preeminently the result of the interaction of man and nature. Thus nature and art are not identical and can not be identical; for art is derived not alone from its external inspiration, its objective source, but from the artist as well. It has a subjective element that can not be divorced from it. Although photographs made by different cameras may be alike, paintings made by different artists can not be.

In spite of the strong subjective element, however, it is obvious to artist as well as layman that much, probably most, of the art of a people consists of some kind of representation of natural objects, either topographic features, plants or animals, including, of course, man himself. Much conventional design has its origin in nature. Such a statement is perhaps less true of the art of an urban community, for there man's surroundings have been considerably modified by his own efforts, but in general, and especially in reference to countries with a traditional art of long standing, we may say that the art is derived chiefly from the natural environment.

Furthermore, and this assumption is generally made by archeologists, the most familiar objects occur with greatest frequency. Conversely, one assumes that if an object occurs frequently in the art of a primitive people that object was familiar to the people of whom the artist was a representative. Only recently, Dr. George Sarton[1] has made use of this assumption in suggesting that the existence of sexuality in the date palm was known, empirically at least, to the Assyrians of the ninth century B. C. Of course, where the art of a people may be studied with contemporary historical documents, this apparent assumption is thoroughly validated. Thus it is probably true that the most common subjects

[1] *Isis*, XXI: 8–13, 1934.

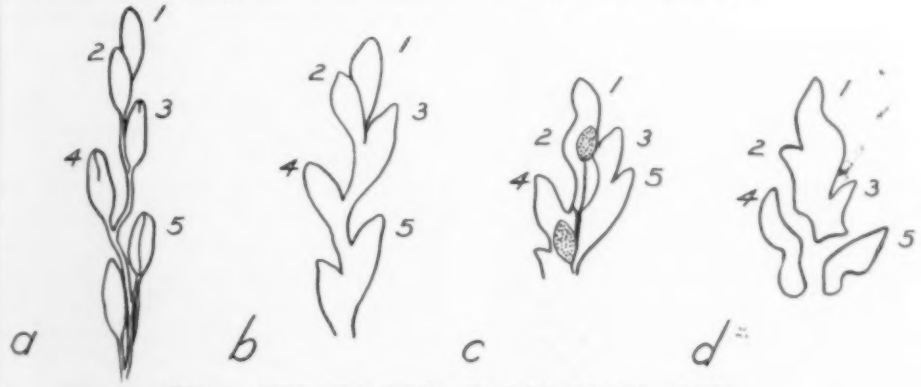

FIG. 1. THE EVOLUTION OF THE *KANOK* DESIGN.

THE FOUR FIGURES ABOVE REPRESENT THE POSSIBLE STEPS IN THE DEVELOPMENT OF THIS SIAMESE DESIGN FROM THE INFLORESCENCE OF THE RICE. a. A HEAD OF RICE. b. HYPOTHETICAL ANCESTRAL STAGE OF THE DESIGN. c AND d. CONTINUOUS AND BROKEN DESIGNS COPIED DIRECTLY FROM COMPARATIVELY RECENT AND RECENT ART OBJECTS, RESPECTIVELY.

FIG. 2. THE *KANOK* IN STONE
IN BOLD RELIEF. SKETCHED FROM THE CRAYON (EIGHTH CENTURY A. D.) IN ANGKOR T'OM.

in a people's art are those things with which that people is most familiar.

As a corollary of the above, we assume further that the objects with which the artist is most familiar are represented most realistically. This does not mean, of course, that two artists, having equal familiarity with an object, depict that object with equal reality. However, it is in general true that familiar objects occur not only most frequently but are represented with the greatest fidelity to nature; although an object that has been conventionalized, and that has been used in art for many centuries, sometimes loses, in the form of representation, much of the appearance of its source.

FIG. 3. CARVING IN ANGKOR WAT.
THE *kanok* HERE OCCURS AS A COMMON MOTIF ON A LIMESTONE PILLAR.

FIG. 4. BOOK COVER DECORATIONS.
PART OF THE DESIGN ON A MODERN SIAMESE BOOK-COVER. ENLARGED.

The most widely used design in Siam to-day, and perhaps for centuries past, is the *kanok* (also transliterated *ganok*, the initial sound being between the English *k* and *g*). The pattern is somewhat ornate and complicated, and appears, superficially, to have been derived from tongues of flame. In fact, certain types of the *kanok* pattern are said by Siamese students of their own art to have been taken from the flame. It seems generally recognized as a part of Siamese tradition, on the other hand, that the *kanok* is a rice pattern, that it was derived from the inflorescence of the

rice plant. It may have been modified in the direction of the flame pattern, and obviously has been in many special cases.

Actually, there is little to support this theory of the origin of the design except tradition, for the Siamese name *kanok*, which is derived from a Pali word meaning "end" or "termination," suggests nothing except part of the general form. Perhaps little is to be gained by theorizing as to the actual process of the metamorphosis of the rice inflorescence. If one assumes, however, that the tradition is correct, then one may feel free to imagine the steps in the process. Such the writer has done in Fig. 1.

To-day the kanok ornaments everything in Siam from silver coat buttons to temple doors. It is seen everywhere and is unquestionably the most characteristic design in Siamese art. In the past, its predecessor or counterpart was carved on the Borobudur, in Java, which

FIG. 5. PEACOCK-FEATHER DESIGN USED IN NORTHERN SIAM. NATURAL SIZE. THIS WAS COPIED FROM THE COVER OF A MODERN LACQUER BETEL-BOX. THE LINES IN THE ORIGINAL ARE WHITE ON A BLACK BACKGROUND.

FIG. 6. A *NAGA* OF THE NORTHERN SIAMESE TYPE, AT NAN.

dates from the eighth century A. D. In Cambodia, the *kanok* appears, without question, on the Bayon (eighth century) in the ruined city of Angkor T'om. There it is carved boldly, in rather high relief (Fig. 2), and contributes the "rich floral design" of some descriptions. In Angkor Wat (completed in the twelfth century) it occurs as a common motif. The beautifully delicate carving on a stone pillar in this famous temple is reproduced in an accompanying photograph.

The Siamese probably acquired this design, as well as certain other characteristics of their art, in their more than two centuries of conflict and other commerce with Cambodia preceding the desertion of Angkor by the Cambodians in the 1430's. In time of origin the *kanok*

FIG. 7. ROYAL BARGE WITH NINE-HEADED *NAGA* AT THE BOW.

must, in any case, antedate the classical period of Cambodian art, for it had already become highly developed by the eighth century. But the rice plant has long been cultivated in southeastern Asia, and the ultimate source of the design may well have been this familiar plant—regardless of the time or place of origin.

Present-day modifications of the design have become, in many cases, exceedingly intricate. Figures of various

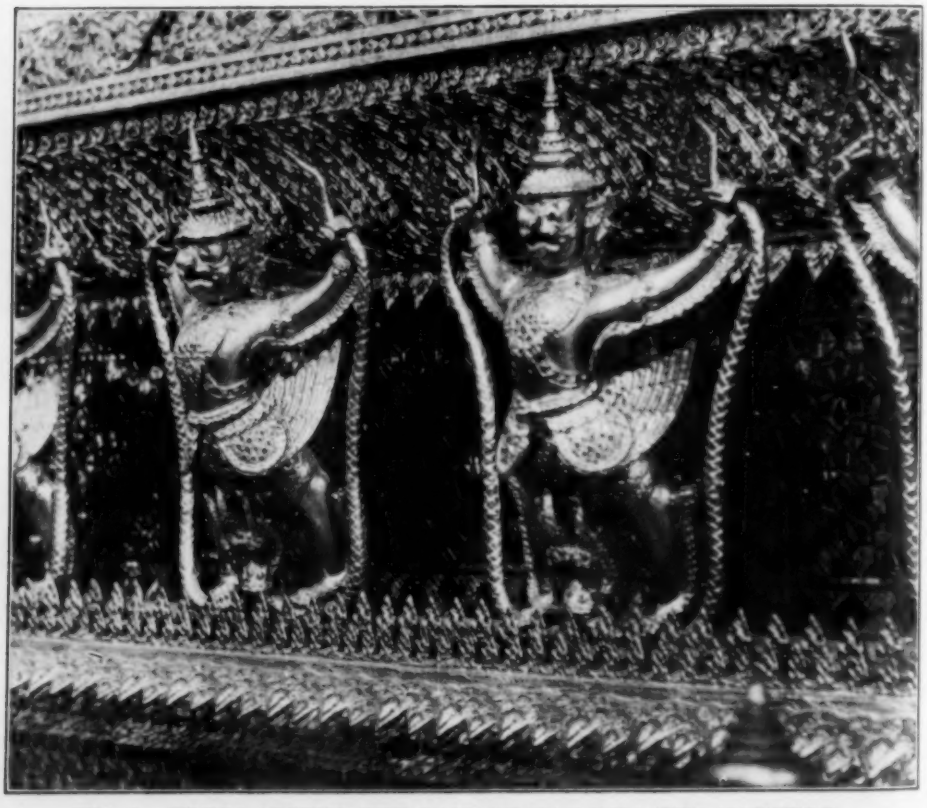

FIG. 8. *KRUTS* AROUND THE BASE OF WAT P'RA KEO, BANGKOK.

mythical creatures, in many different poses, form essential elements of the major design. In Fig. 4, a bit of detail from a modern decoration for a book cover serves to illustrate this well. The broken pattern (Fig. 1, d), illustrating the fourth stage in the development of the *kanok*, is taken directly from this design.

Two other conventional designs in common use are probably of natural origin. The *mali*-pattern is a modified floral design said to be derived from the leaves of the jasmine (*dok mali*, in Siamese). It has been a common decorative motif in central Siam. In northern Siam, a peacock-feather design is commonly used in the decoration of lacquerware (Fig. 5). This suggests an influence from Burma, rather than Cambodia, and illustrates the general principles that the art and architecture of northern Siam show closest affinity with those of Burma, whereas in central Siam the closest relationship is with Cambodia, to the east.

FIG. 9. *SING-TO*
A MYTHICAL LION, AND FRAGMENTS OF TWO *nagas* OF THE CAMBODIAN TYPE. ANGKOR.

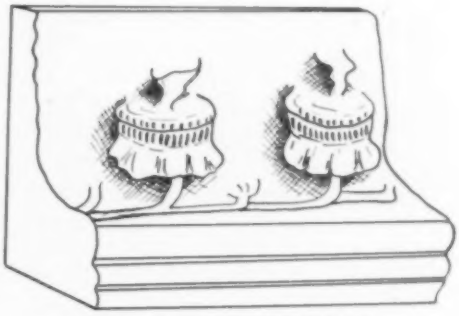

FIG. 10. LOTUS DESIGN
FROM THE BAYON, ANGKOR T'OM.

A host of monsters, which figure in the legends of southern Asia, decorate the temple grounds of Siam. To the visitor, the most interesting of these, and at the same time the most characteristic, are the *naga* (a serpent or dragon) and the *krut* or *garuda*, which is part man and part eagle. The first of these is, in the art of Cambodia[2] and Central Siam, unquestionably a hooded cobra, with, however, three, five, seven or even more

[2] H. Marchal, "Guide archéologique aux temples d'Angkor" (Paris, 1928). M. Marchal states explicitly that the *naga* is the conventionalization of the cobra. He also suggests that the *naga* and the *krut* are the most representative motifs in Khmer (Cambodian) sculpture and decoration.

FIG. 11. A CONVENTIONALIZED
LOTUS DESIGN FROM UNDER SIDE OF STONE CEILING BEAM, ANGKOR WAT.

FIG. 12. A SMALL TOWER OF LOTUS DESIGN, IN ANGKOR T'OM. ABOUT TENTH CENTURY.

FIG. 13. A STONE ELEPHANT OF CAMBODIAN WORKMANSHIP, ABOUT 945 A. D. (PHOTOGRAPH BY MRS. FRANCES DAVIES.)

FIG. 14. WALL CARVING IN THE BAYON, ANGKOR T'OM. (PHOTOGRAPH BY MRS. FRANCES DAVIES.)

heads. In northern Siam, the creature which goes by the same name is not a cobra at all (Fig. 6). It is much more like the dragons of China, and is perhaps really a modified Chinese dragon with a Siamese name! There is at the P'ya T'ai Palace, Bangkok, a fountain in which the water flows from the mouth of a so-called *naga*, which is of the northern type, but with feet bearing claws. It is really a Chinese dragon in all but name.

I have occasionally heard people refer to the "plumed serpent" of Angkor. The *naga* is what is meant, but it should be noted that the resemblance between the *naga* and the serpent representation of the Mayas is extremely remote. There is no evidence in this figure-type for communication between the Old and New Worlds.

The *krut* or *garuda*, like the *naga*, has a wide occurrence in the art of south-eastern Asia. It is a creature of great significance in the legends of India, where its rôle is that of the bearer of Vishnu through the sky. Its regal significance has been recognized in Siam, where it has been used as a symbol of officialdom. The *krut* is a bird-man hybrid. As also in the myths of the Hellenic world, numerous hybrid, mythical creatures occur in those of Further India and are consequently reproduced in its art.

A row of large, gilded *kruts* surrounds the base of the principal building of Wat P'ra Keo, the "Temple of the Emerald Buddha," in Bangkok. The accompanying Fig. 8 shows not only a few of these, but *nagas*, whose heads are held down by the feet of the *kruts*. The two are combined frequently in art. In several of the ruins at Angkor a *krut*, with arms outspread, rests, with body arched backward, on the seven hooded, upraised heads of the *naga*. This usually forms the lower end of a balustrade, of which the long, cylindrical body of the serpent forms the coping.

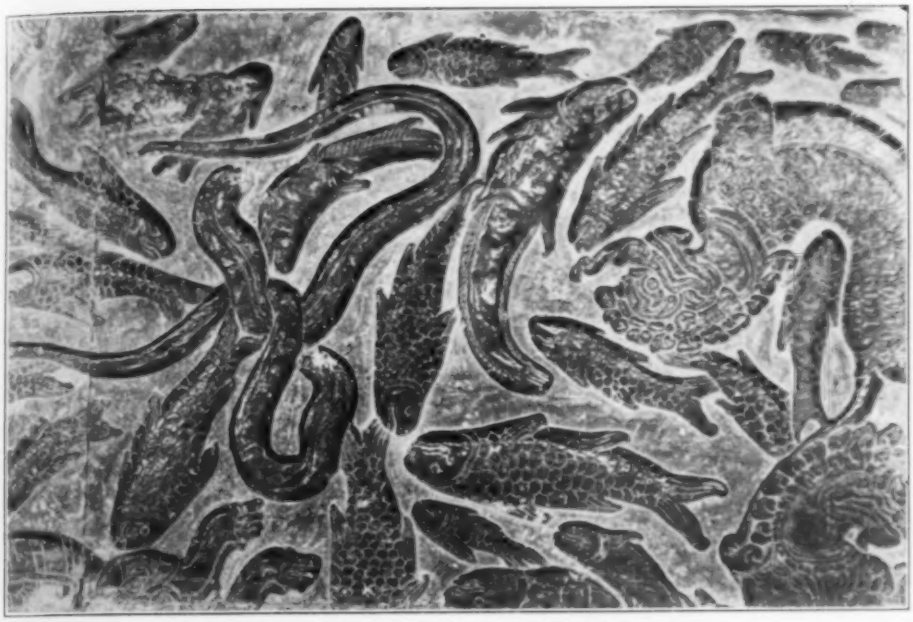

FIG. 15. WALL CARVING IN ANGKOR WAT.

FIG. 16. A PORTION OF THE ELEPHANT TERRACE, ANGKOR T'OM.

More realistic representations are common enough, either as pictures pure and simple, or as a means of decoration. For the latter purpose, carved designs adapted from the lotus flower and seed receptacle occur frequently at Angkor. Some of the designs are very realistic; others have developed into a conventionalized, more or less geometrical, pattern. Sketches to illustrate the two types, as made by the writer at Angkor, are here reproduced in Figs. 10 and 11. The form of the lotus has probably contributed a great deal to the architecture of southern Asia. The accompanying photograph of a small tower in Angkor T'om, probably antedating the eleventh century, is of obvious lotus design. It is even possible that the *stupa* and the various forms of temple towers in Further India—either the tall spire (*chedi*) or the rather broadly-truncate tower (*prang*) of Cambodia—are of lotus origin.

FIG. 17. TIGERS
PAINTED ON A TEMPLE EXTERIOR AT NAN, SIAM.

FIG. 18. A PEACOCK
IN PORCELAIN MOSAIC. THIS IS OVER A TEMPLE DOORWAY, CHIENGMAI, SIAM.

Pictorial representation of animals and plants occurs on an enormous scale in the bas-reliefs at Angkor, not only in the more extensive and recent ones of Angkor Wat, but also in the coarser work in earlier buildings, such as the Bayon in Angkor T'om. In the Bayon, although the work lacks the polish and refinement of the later artists, the subjects are executed with great skill, and, in faithfulness of representation, compare well indeed with that coming several centuries later (Figs. 14 and 15). There is nothing in modern Siam to compare with these but there are large frescoes in several Bangkok temples, some of these paintings as recent as the present decade. It is worthy of note that no appreciable change can be observed in the more essential domestic processes since the time of the earliest reliefs in the Bayon, carved a thousand years ago. This statement is appropriate, of course, to the peasant class only. The Siamese farmer of to-day uses practically the same cooking utensils and tools that his predecessors did ten centuries ago; and

this in spite of the fact that he is familiar with guns, irrigation pumps and motor-cars!

As one might expect, the elephant is represented with considerable frequency. In Angkor T'om is the famous elephant terrace, a wall more than a thousand feet long and a dozen feet high, carved in relief to represent an elephant hunt in the forest. The elephants are nearly life-size. In the battle-scenes carved in the galleries of Angkor Wat elephants occur commonly. Also at Angkor, there are in full sculpture four large stone figures of elephants, one at each of the four corners of the building known as the Eastern Mebon. These were carved probably about 945 A. D. In the later, authentically historical, scenes in the frescoes of Bangkok temples elephants are represented in all the glory and gore of battle as well as in the panoply of royal ceremonials. The accuracy of the representations is remarkable. This is probably to be explained in the great familiarity of the artists with the object of their art, an animal which, until recently, was very extensively used in Siam.

Success in portraying the tiger, on the other hand, is, from my own observations, never very successful. The artist could never become as familiar with its form as with that of the elephant, in spite of the fact that he may frequently have seen dead individuals. Attempts at representation of the tiger are not numerous, and often seem to result in grotesques, as illustrated in the photograph (Fig. 17) from a temple at Nan, in a region in which tigers still occur and were formerly quite common.

Around Chiengmai, where the peacock-feather design is so extensively used in lacquer ware, pictorial representation of the peafowl, a bird of the northern jungles, occurs. A photograph of such is here reproduced (Fig. 18). In this case, it is a porcelain mosaic over the entrance to a temple. The frequent use of this bird in art may be associated either with its occurrence in this region or with the nearness to Burma, where its use in art, as in India, is quite common.

Only a most extensive study would bring to light all the uses of nature by the Siamese or Cambodian artist. This outline is merely a suggestion of the extent to which animals and plants determine the art motifs of this particular culture, and, indirectly, of any culture.

WHAT IS ELECTRICITY?[1]

By Dr. PAUL R. HEYL
NATIONAL BUREAU OF STANDARDS

I TRUST that there is no one in this audience so optimistic as to suppose that because I have asked this question I am going to answer it, nor so pessimistic as to fear that because I have asked a question which I can not answer I can offer you nothing but platitudes. I believe it possible in this case to avoid both Scylla and Charybdis.

This question, said the late Professor John Trowbridge,[2] of Harvard University, is often asked as though it were capable of a short and lucid answer which might be understood by any person of liberal education. Many answers have been given, but it is interesting to note that the more definite and confident the answer the older it is, and that as we ascend the ladder of time toward the present day such answers as we encounter are less definite and more cautious.

I think that it will be interesting for us to review, perhaps rather briefly, the ideas which have been held at various times as to the nature of electricity, and then, looking over the wealth of physical discovery which has been amassed in the past forty years, to endeavor to select from it such facts as may be of importance in guiding and controlling future speculation on this question; for though such speculation has been at a minimum, if not a standstill, during the twentieth century, it will doubtless revive again. Speculation or, as it has been otherwise termed, "apt conjecture, followed by careful verification," has been behind much of the advance of science. Such was the method of Faraday and of Darwin. The conjectures of the ancients, having little in the way of observed fact to guide them, might range far and wide, and had small heuristic value, but with the growth of experiment the range of conjecture has continually narrowed and its value as an aid to farther progress has steadily increased.

The beginning of our knowledge of electricity is lost in the mists of antiquity. What we can recover of it is excellently told by Park Benjamin in his history entitled, "The Intellectual Rise in Electricity."[3] It is customary to credit Thales (600 B.C.) with the first observation of the attractive power of rubbed amber, but Benjamin shows that amber was widely known among the ancients for centuries before Thales. Beads of amber have been found in the ancient lake dwellings of Europe, in the royal tombs at Mycenae (2000 B.C.) and throughout northern Italy. The identity in chemical composition of these relics with the amber of the Baltic sea coast is significant of the esteem in which this substance was held and of the distance over which it was thought worth while to bring it. The golden glow of the polished beads suggested the beaming sun, called by Homer ἠλέκτωρ, which doubtless gave rise to the Greek name for amber, ἤλεκτρον.

It is incredible, as Benjamin points out, that this wide-spread acquaintance of the ancients with amber should have existed so long without its electrical

[1] The fifth Joseph Henry Lecture presented on March 30, 1935, before the Philosophical Society of Washington in honor of its first president. Publication approved by the director of the National Bureau of Standards of the U. S. Department of Commerce.

[2] Trowbridge, "What is Electricity?" London: Kegan Paul, Trench, Trubner and Co., 1897.

[3] London, Longmans, Green and Company, 1895.

property being often noticed. It is probable that Thales but shared the knowledge of his time in this respect, for his acquaintance with the things of nature in general was such as to enable him to make the first recorded prediction of an eclipse of the sun. Thales left no writings of his own, and all we know of him we have learned from those who lived several centuries later.

It appears from these authorities that the ancients regarded electricity as a soul or spirit resident in an otherwise lifeless substance. This was in harmony with the prevailing thought of the times, which regarded all motion as evidence of life. The air was inanimate, but the wind was the breath of Aeolus; the waves of the sea were excited by the wrathful strokes of Neptune's trident; the lightning was the thunderbolt of Zeus. This animistic explanation of the nature of electricity was simple and definite enough to be understood by any one, and lasted for several millenniums; in fact, until the revival of learning and the growth of experimental science supplied material upon which to base a rival theory.

We are helped to realize this animistic point of view when we read in a translator's footnote to Gilbert's book on "The Magnet"[4] that a certain ancient physician recommended the administration of doses of powdered lodestone in cases of estrangement between husbands and wives. Given the premises of the time, such a conclusion was perfectly logical. It was obvious that the patients exhibited a deficiency of a certain spiritual element which was found in the lodestone, and the administration of that medicine followed as naturally as a modern prescription of cod liver oil because of its vitamin content.

It was the middle of the sixteenth century before the next answer on record was given to the question, "What is electricity?" This answer came from Cardan,[5] whose name is familiar to mathematicians (perhaps more so than it deserves to be). Cardan was the originator of the fluid theory of electricity which held the stage in one form or another for over three centuries, and survives to-day in popular parlance in the term "the electric fluid" or, still more colloquially, "the juice." Cardan passed from the spiritual to the material in his explanation, which was that amber "has a fatty and glutinous humor which, being emitted, the dry object desiring to absorb it is moved towards its source, like fire to its pasture; and since the amber is strongly rubbed, it draws the more because of its heat."[6]

In this last sentence we see the influence of Cardan's profession. He was, among other things, a physician, and was accustomed to warm the cupping glass in drawing blood from his patients. The laws of pneumatics were not yet understood at that time, and it was generally supposed that the cupping glass acted because of its heat.

The fact that this "fatty and glutinous humor" was intangible and invisible seems to have caused Cardan no embarrassment. We may perhaps view this the more charitably when we think of the contradictory attributes that later scientists have found it convenient to assign to the luminiferous ether.

The year 1551 in which Cardan published this theory may be taken as marking the end of the first era, in which electricity was regarded as a soul or spirit. Its beginning goes back beyond recorded history.

The concept of electricity as a material substance contained in certain bodies known as electrics was strengthened by the experiments of Gilbert

[4] Translation by P. Fleury Mottelay, New York, John Wiley and Sons, 1893, page 56.

[5] Cardan, *De Subtilitate*, Lib. XXI, Paris, 1551.

[6] Park Benjamin, *op. cit.*, p. 248.

(1600), who showed that many substances besides amber were to be included in this class, but the full development of the fluid theory of electricity did not come until the middle of the eighteenth century. In the meantime, von Guericke (1672) had invented his sulphur globe electrical machine, which made electrical experimentation easy on a large scale. With the facilities thus placed at his disposal he discovered electrical conduction and electrostatic repulsion, the latter destined to be a phenomenon of prime importance in later speculation on the nature of electricity.

In the eighteenth century development of the fluid theory two names are prominent, those of Du Fay and Franklin, each typifying a separate trend in theory.

Du Fay's experiments (1733 and later) chronologically preceded those of Franklin. His most important discovery was that glass when rubbed behaved in one respect quite differently from amber; a bit of gold leaf excited by contact with the glass tube is then repelled by the glass but attracted by excited amber. "And this," said Du Fay, "leads me to conclude that there are perhaps two different electricities." These he distinguished accordingly as vitreous and resinous, and laid down the law that like electricities repel each other and unlike attract.

To explain the same phenomenon Franklin (1747) postulated a single electric fluid of which all bodies were normally full. If a body acquired more than this normal amount he called it "plus," or positively electrified, and if its charge was less than normal, "minus," or negatively electrified.

Franklin's hypothesis had simplicity in its favor; it required one less assumption than that of Du Fay. In this respect it obeyed more closely the rule laid down by Newton: "We are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances . . . for Nature is pleas'd with simplicity and affects not the pomp of superfluous causes."[7]

This simplicity of Franklin's hypothesis, added to the reputation which he himself rapidly attained in scientific circles, gave the one-fluid theory an advantage over its competitor for the time being, but a serious theoretical objection was soon raised against it. Since on this theory a negative charge meant a deficiency of electric fluid, there must be a limiting value of negative charge, namely, when the body is completely emptied of the electric fluid; but two such bodies, both being negatively charged, should repel each other—and why?

There was much hesitancy on the part of the one-fluid advocates about pushing this argument to its logical conclusion. It remained for a bold German named Aepinus (1759) to seize the bull by the horns and assert that matter devoid of electricity is self-repellent.

This doctrine came as a shock to a generation many of whom could remember Newton. It was useless to point out that Newton had deduced the law of gravitation by observation of bodies that possessed their normal amount of electricity, and that the behavior of matter with the maximum negative charge was something which no one had ever observed. The one-fluid theory had received a serious jolt from which it never recovered; this argument was used against it as late as the 1830's. The attention of theoretical physicists of the eighteenth century was turned toward the two-fluid theory, and during the closing years of that century and the early part of the nineteenth the work of Coulomb, Laplace, Biot and Poisson produced an elaborate and elegant mathematical theory which so well described

[7] Newton, "Principia," Book III: "Rules of Reasoning in Philosophy."

all the electrostatic phenomena then known that by 1830 the two-fluid theory was generally accepted.

But it often happens that as soon as one theory is comfortably settled on the throne another rises up to challenge its supremacy. We shall see the reign of each successive theory of electricity growing shorter. The thousands of years of the first era were followed by three centuries of the second. In the first half of the nineteenth century great things were happening. In 1820 Oersted had discovered that an electric current could produce a magnetic effect, thus tying together what had previously been regarded as separate phenomena. In 1822 Seebeck showed that electricity could be generated by heat. These discoveries impressed themselves on the mind of Faraday, then at work in the Royal Institution. He was familiar with the work of Davy in producing chemical decomposition by electricity, and the converse phenomenon of Volta, the production of electricity by chemical action. Faraday was also aware of the converse of Seebeck's discovery, the production of heat (and light) in the electric arc, and his thoughts turned naturally toward the undiscovered converse of the Oersted effect. He says himself at a later time[8] (1845):

> I have long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, into one another, and possess equivalents of power in their action. In modern times the proofs of their convertibility have been accumulated to a very considerable extent, and a commencement made of the determination of their equivalent forces.

Such were the considerations which led Faraday to attempt the generation of electricity by means of a magnet (1831). The story is familiar to all of us; how he placed a magnet in a helix of wire and found that no current was produced except momentarily while the magnet was being placed in or taken out of the coil. This discovery seems to have made quite an impression in other than scientific circles, as is evidenced by some verse which has come down to us:

> Around the magnet, Faraday
> Is sure that Volta's lightnings play.
> To bring them out was his desire.
> He took a lesson from the heart;
> 'Tis when we meet, 'tis when we part,
> Breaks forth the hid electric fire.

Encouraged by this success, Faraday later (1845) sought and found a correlation between magnetism and light. Twenty years later this in its turn furnished the inspiration for Maxwell's electromagnetic theory, by means of which the domain of optics was annexed to that of electricity.

The publication of Maxwell's paper in 1865 may be considered as closing the second era of electrical theory, that in which electricity was regarded as a material fluid, and the opening of the third era in which the concept of electricity assumed a less material and more elusive form.

By 1865 the two great doctrines of nineteenth century physics, the conservation of energy and the correlation of physical forces (as foreshadowed by Faraday) had been enunciated and were well on the way to general acceptance. During the seventies and early eighties electricity, in common with heat and light, was sometimes called, in the phrase of the day, "a mode of motion," which meant a form of energy.

The adoption of this view was, of course, a matter of slow growth. Maxwell's electromagnetic theory had a long struggle for acceptance, so long, in fact, that Maxwell himself did not live to see its final triumph. He died in 1879, and

[8] Faraday, "Experimental Researches in Electricity," Vol. 3, p. 1, London, 1855.

it was not until 1886, when Hertz produced experimentally the electromagnetic waves which Maxwell's theory demanded, that its acceptance may be said to have become complete.

Against this concept of electricity as a "mode of motion," that is to say, a form of energy, Lodge[9] in 1889 entered a protest. He pointed out that water or air under pressure or in motion represents energy, but that we do not therefore deny them to be forms of matter. He emphasized an important distinction between two terms: *electrification*, which is truly a form of energy, as it can be created and destroyed by an act of work, and *electricity*, of which none is ever created or destroyed, it being simply moved and strained like matter. No one, said Lodge, ever exhibited a trace of positive electricity without there being somewhere in its immediate neighborhood an equal quantity of the negative variety.

Lodge did much to crystallize the ideas of the time concerning the nature of electricity. These ideas, since Maxwell's merger of optics with electricity, had been, as Lodge pointed out, not clearly defined, but in general the idea was that electricity was in some way a phenomenon of the ether. Lodge enlarged upon this idea, explaining electrostatic phenomena as due to ether stress, electric currents as ether flow and magnetism as ether vortices. Electricity, which had been previously regarded as a material fluid, now became an immaterial one, and in consequence this third period of electrical theory may be called the ethereal era.

As we mount toward the present time we see the different eras of electrical theory rapidly shortening in duration. While the spiritual era lasted several millenniums and the fluid theory three centuries, the ethereal era lasted only a few decades. The fourth era is that which is still with us. It may be called the atomic or quantum period, in which it is noteworthy that but little attention has been paid to the ultimate nature of elecricity and a great deal to its structure. It is difficult to say when this period began, as, in fact, the ethereal era began to die almost as soon as it began to live.

Wilhelm Weber,[10] in 1871, in developing his theory of magnetism, pictured to himself light positive charges rotating about heavy negative ones, much like a satellite about a planet; and in 1874 Johnstone Stoney read before Section A of the British Association a paper entitled, "The Physical Units of Nature," which was not printed until seven years later.[11] In this paper he asserted the atomic nature of electricity and made a rough calculation of the elementary charge on the basis of Faraday's law of electrolysis. Ten years later[12] he was the first to use the term "electron."

Helmholtz,[13] in his Faraday lecture at the Royal Institution in 1881, further developed this line of thought, saying (page 290):

> Now the most startling result of Faraday's law is perhaps this. If we accept the hypothesis that the elementary substances are composed of atoms, we cannot avoid concluding that electricity also, positive as well as negative, is divided into definite elementary portions, which behave like atoms of electricity.

Maxwell himself saw that his electromagnetic theory was essentially continuous in its nature and recognized the difficulty arising from the implications of Faraday's experiments. In his "Treatise on Electricity and Magnet-

[9] Lodge, "Modern Views of Electricity," p. 7, London, Macmillan and Company, 1889.

[10] Millikan, "The Electron," p. 20, University of Chicago Press, 2nd edition, 1924.

[11] Stoney, *Phil. Mag.*, 11: 381–390, 1881.

[12] Stoney, *Sci. Trans. Royal Dublin Society*, IV: 1891, 11th series, p. 563, 1891.

[13] Helmholtz, *Journal of the Chemical Society (London)*, 39: 277–304, 1881.

ism" (1873, Vol. 1, Chap. IV, page 313) in the chapter on electrolysis he says: "It is extremely improbable that when we come to understand the true nature of electrolysis we shall retain in any form the theory of molecular charges."

For Helmholtz, however, the atomic nature of electricity was beyond question. Electricity, as he saw it, was a special chemical element[14] whose atoms combine with those of other elements to form ions. Moreover, it appeared to be a monovalent element, for it seemed that a monovalent element combined with one electron, a bivalent one with two, and so on, exactly as a chlorine atom combines with one atom of hydrogen and an oxygen atom with two atoms of hydrogen. Helium, with its zero valence and double electrical charge, was as yet unknown.

The inevitable process of reconciliation of these contradictory theories was early begun by Lorentz,[15] who suggested for this purpose his electron theory of electricity. On this theory all the effects of electricity inside bodies were explained on the assumption of electrons, and all the effects of electricity at a distance, electrostatic, electromagnetic and inductive, required the help of the ether. To unite these two classes of phenomena he assumed that each electron was closely bound up with the ether, and that any change in configuration of the electrons produced a change in the ether which was propagated with the velocity of light, and thus produced action at a distance.

About this time an entirely new line of experimental research was developing which was destined eventually to make the atomic concept of electricity dominant for a time. This was the study of the electric discharge in high vacua. Several workers had investigated this field without attracting much notice, but it remained for Crookes to direct widespread attention to this class of phenomena by an exhibition of novel and beautiful effects in vacuum tubes which he gave at the meeting of the British Association at Sheffield in 1879. Crookes unquestioningly assumed these effects to be due to electrified molecules of residual gas in the tube. It was shown later by others (J. J. Thomson, Townsend, Wilson, Millikan) that the negatively charged particles in a Crookes tube were not molecules or even atoms, but bodies of a minuteness previously unknown, about the 1/1800th part of a hydrogen atom in mass, and bearing a definite negative charge of electricity. For these tiny bodies the term electron, introduced by Stoney, was revived. Still later work brought to light the proton, with an equivalent positive charge but larger mass than the electron and, in our own day, the positive electron.

As the result of this new line of investigation it became clear that a great many electrical phenomena required the atomic theory of electricity for their explanation. A great many, but not all; for a large number refused to fall in line under a corpuscular explanation, but could be simply and completely explained on Maxwell's theory as ether disturbances. The discovery by Hertz of the electromagnetic waves predicted by Maxwell did much to swing the pendulum back in this direction. The reconciliation of these contending views has been carried on much along the line originally taken by Lorentz. It is of interest to note that his idea of an electron inseparably bound up with the ether is found to-day in all essentials in the theory of wave mechanics.

We have now brought this somewhat hurried survey of electrical history up to the present day. We have seen that past speculations as to the nature of electric-

[14] Graetz, "Recent Developments in Atomic Theory," London, Methuen and Co., 1923.

[15] Lorentz, *Verslagen en Mededeelingen der Koninklijke Akademie van Wetenschappen*, Amsterdam, 8: 323–327, 1891. Also *Archives Neérlandaises*, 25: Chap. IV, pp. 432 *et seq.*, 1892.

ity fall into four classes, each corresponding to an era of thought. In the first of these eras, beginning probably with the earliest observations of electrical attraction and terminating in the middle of the sixteenth century, electricity was regarded as a soul or spirit. The second era may be said to have been opened by Cardan in 1551 and closed by Maxwell in 1865. During these three centuries electricity was regarded as a material fluid of one or two kinds. It is worthy of note that during this period the concept of the electrical fluid showed a trend toward the immaterial, from Cardan's "fatty and glutinous humor" to the impalpable and imponderable fluid of the early nineteenth century. In the third era electricity in its various manifestations was regarded as some kind of an ether disturbance of a continuous nature. The fourth concept emphasized the atomic or discontinuous structure of electricity without any suggestion as to the ultimate nature of these atoms.

But though speculation as to the ultimate nature of electricity has been in abeyance since the opening of the twentieth century it will certainly arise again, and within limits it is well that it should. We may therefore turn now to an examination of the wealth of material which the last forty years have placed at our disposal and see what it may contain that is likely to be of importance in guiding and suggesting future speculation as to the nature of electricity.

The emphasis laid by the twentieth century on the structure rather than the nature of electricity is natural, for structure is much more easily determined than nature, and moreover a knowledge of the first is likely to give us some useful hints as to the second. It appears that the discontinuous structure of electricity goes almost hand in hand with that of matter. A tabular view of the known elementary particles of matter with their associated charges of electricity will be useful.

	Charge	+	−	0
Mass	Heavy	Proton	.....	Neutron
	Light	+ Electron	− Electron	(Neutrino)

The heavy particles now known, the proton and the neutron, have a mass equal to that of a hydrogen atom; the light particles have about 1/1800 of this mass. The light neutral particle has not yet been discovered, but so urgent is the demand for it in current nuclear theory that it has been named before its advent.

According to the idea that has prevailed for two centuries, positive and negative electricity should be merely reflected images of each other, their properties being equal and opposite. The behavior of the negative electron and the proton shows nothing inconsistent with this concept as far as electrical properties go. On the discovery of the positive electron it was at first thought that it was shorter lived or, as a chemist might say, more reactive than its negative counterpart, but this has not been borne out by subsequent investigation.[16] The mass associated with the positive charge in this case has been investigated by several persons. The latest work is that of E. Rupp,[17] who finds that the mass is within 5 per cent. of that of the negative electron. Rupp appears to have found one point of difference between the two which, if confirmed, will be of importance.

It has been found that the passage of negative electrons through thin films of metal is accompanied by a diffraction effect, photographs of the electron beam after transmission showing a series of concentric rings. Rupp passed negative and positive electrons through the same films of gold and aluminum, and found

[16] Allowing for relative abundance.

[17] Rupp, *Phys. Zeit.*, 35: 999, 1934. But in *Zeit. für Physik*, 93, 278, 1935, Rupp has withdrawn his earlier article for revision.

that while the negative particles gave the usual rings the positive particles showed a continuous scattering. We will return to the interpretation of this later.

As to the neutron, it is still uncertain whether it is a proton which has acquired a negative electron or whether it is to be regarded as an independent entity without electric charge. The latter, as we shall see later, would be in serious conflict with present accepted electrical theory.

There was a time, not so very long ago, when the atom of matter was considered to be its ultimate structural unit. The discovery of the proton and the electron gave meaning to the term "sub-atomic." With this in mind, the question naturally arises as to a possible further subdivision of the electron. Several observers have claimed to have found evidence of smaller charges than that carried by the electron, but Millikan,[18] after an exhaustive discussion of the subject, came to the conclusion that up to 1924 there had been adduced no satisfactory evidence of this smaller charge.

In the early years of the present century there was some discussion as to whether the electron was to be regarded in shape as a rigid sphere (Abraham) or as contractile. The latter hypothesis was advanced by Lorentz to explain the negative result of the Michelson-Morley experiment. Lorentz supposed the electron, by motion through the ether, to flatten into an oblate spheroid. Experiments by Bucherer[19] in 1909 were interpreted as favoring the hypothesis of Lorentz.

But in 1927 a new line of experimental evidence as to the structure of the electron was opened up by Davisson and Germer,[20] soon followed by G. P. Thomson.[21] These investigators found, in brief, that electrons (of the negative variety) might be scattered by reflection or diffracted by passage through very thin films of metal in such a way as to suggest that an electron is at least as much like a little bunch of waves as it is like a particle, and that neither aspect can be ignored.

This is well brought out by G. P. Thomson's diffraction rings. The electron must have a wave aspect, or there would be no interference pattern; it must have a charged particle aspect, or the whole ring system would not be deflected by a magnet, as it is found to be. The whole situation, in fact, had been foreshadowed theoretically by the wave mechanics of de Broglie and Schrödinger.

A number of explanations have been offered for this dual behavior. Perhaps the most completely worked out is that of J. J. Thomson,[22] based upon the diffraction rings obtained by his son, which lend themselves particularly well to theoretical treatment. On this view the electron is associated with and accompanied by a group of waves which guide and direct its motion. Now it was found by a study of the speed of the electrons and the associated wave-lengths in the diffraction rings that a curious and complicated relation existed between these quantities. If u is the velocity of an electron and λ its associated wave-length, this relation is:

$$\frac{u\lambda}{\sqrt{1-u^2/c^2}} = C \qquad (1)$$

in which c is the velocity of light and C is a constant.

But this, as J. J. Thomson shows, is exactly the relation that should hold for the group speed of electromagnetic

[18] "The Electron," Chap. VIII.

[19] Bucherer, *Annalen der Physik*, 28: 513, 1909; 29: 1063, 1909.

[20] Davisson and Germer, *Nature*, April 16, 1927; *Phys. Rev.*, 30: 705, December, 1927.

[21] G. P. Thomson, *Proc. Roy. Soc.*, 117: 600, February 1, 1928.

[22] J. J. Thomson, "Beyond the Electron," Cambridge University Press, 1928; *Phil. Mag.*, 6: 1254, December, 1928.

waves in a medium such as the Kennelly-Heaviside layer, containing a multitude of electric charges, positive and negative.

J. J. Thomson, therefore, suggests the following structure for the negative electron:

I. A nucleus which, like the older concept of the electron, is a charge of negative electricity concentrated in a small sphere.

II. This nucleus does not constitute the whole of the electron. Surrounding it there is a structure of much larger dimensions which may be called the sphere of the electron. This sphere contains an equal number of positive and negative charges, forming a little Kennelly-Heaviside layer around the nucleus. Measurements on the diffraction rings indicate a diameter for this sphere at least 10,000 times that previously accepted as the diameter of the electron.

III. The nucleus is the center of a group of waves and moves with the group speed in its atmosphere of electric charges.

At the time that J. J. Thomson proposed this hypothesis the positive electron was not known. Here comes in the importance of Rupp's work previously referred to (Reference 17). On their face, these experiments indicate either that the train of waves that accompanies a negative electron is absent from the positive electron or that all possible wave-lengths are present.

Just as the atom, once regarded as an ultimate structural unit, is now recognized as a complex of electrons, protons, neutrons and possibly neutrinos, so the electron, it seems, must be regarded as a similar complex. Much more, doubtless, is to be learned about its structure before we can hope to answer the question, "What is electricity?"

But perhaps the most outstanding fact in modern physical theory is the dominant position occupied by electricity. In the nineteenth century one spoke of matter and electricity as two separate and independent entities; nowadays electricity has become the fundamental entity of which matter is merely an aspect. Matter, once supreme, has lost its individuality and has become merely an electrical phenomenon of which electricity may exhibit more or less according to circumstances.

It is obvious that our answer to the question, "What is electricity?" will be fundamentally influenced according to whether we hold an electrical theory of matter or a material theory of electricity. It will therefore be worth our while to examine the foundation for the present view that electricity, whatever it may be, is the sole world-stuff. So radical has been this change in our thinking that it would seem a foregone conclusion that it must be based upon the clearest and most unequivocal of experimental evidence.

This change in our concepts did not come suddenly. Its beginning dates back to 1893, when J. J. Thomson[23] showed on theoretical grounds that a charged sphere in motion through the ether would encounter a resistance which to all intents and purposes would appear as an increase in the sphere's inertia, *i.e.*, in its mass. Calculation indicated that this effect would become appreciable only if the velocity of the charged body was comparable to that of light.

In 1893 this suggestion was of academic interest only, no bodies moving with sufficient speed being then available for experiment. A few years later conditions had changed. The study of radioactive substances and of the discharge of electricity through gases had placed at our disposal positively and negatively charged particles moving with unprecedented speeds, which in the case of the negative particles were in some cases comparable with the speed of light. Here, it would seem, was an opportunity to test Thomson's theory of increasing mass.

Unfortunately, the conditions of the problem were such that it was not at

[23] J. J. Thomson, "Recent Researches in Electricity and Magnetism," p. 21, Oxford, Clarendon Press, 1893.

first possible to obtain a measure of the mass of such a particle, but only a determination of the ratio of the electric charge to the mass which carried it (e/m).

Kaufmann[24] found, however, that for the swifter particles this ratio was less than for the slower ones. There were only two ways of explaining this fact, both equally radical: either the mass increased or the charge diminished as the speed of the particle became greater.

In this dilemma opinion inclined generally to the first alternative, largely because there was in existence a theoretical reason to expect it, while no one as yet had been ingenious enough to suggest any reason why a moving charge should alter. It is of importance to note that Kaufmann's experimental result, because of its equivocal character, can not be accepted as more than half proving J. J. Thomson's theory.

Kaufmann calculated that such particles as he experimented with might have, when moving slowly, an "electrical mass" equal to about one fourth their total mass. In making this calculation he assumed that a particle behaved as though it were a little metallic conductor, but he was careful to point out that a different assumption might lead to another result.

And so it happened. J. J. Thomson, on the assumption that a particle had no metallic conductivity, but acted like a point charge, found that Kaufmann's results indicated that the whole of the mass of the particle might be accounted for electrically.

This was the origin of the electrical theory of matter. Its pedigree goes back to J. J. Thomson's theory, which in turn was derived from the electromagnetic theory of Maxwell. Kaufmann's experiments only half proved Thomson's theory, which in addition was complicated by a special assumption with regard to the distribution of the charge on the particle. Without this assumption only a part of the mass could be accounted for electrically.

But much water has run under the bridge since 1893. Forty years is a long life for any physical theory in these days, and the recent discovery of the neutron has brought with it a challenge to the electrical theory of matter.

In J. J. Thomson's original theory of the increase in mass of a moving charge it was an essential point that the lines of force should be free to adjust themselves as the motion demanded. As a leaf or a card tends to flutter down through the air broadside on, so the lines of force, originally distributed radially and symmetrically about the charge at rest, will tend to set themselves in a plane perpendicular to the direction of motion of the charge. They will not all be able to lie in this plane because of their mutual repulsion, but the density of the lines will be a maximum in this plane and a minimum in the direction of motion, and a certain space distribution will result, of such a nature that the apparent increase of mass can be completely accounted for.

But it is essential for this result that the lines of force shall be perfectly free at their outer ends; in other words, only a single isolated charge is considered. Now in a structure like the hydrogen atom, composed of a negative and a positive particle, there is bound to be some interference with this freedom of adjustment. In a neutral, non-ionized atom it would appear that all the lines must begin and end within the atomic structure.

J. J. Thomson must be given credit for foreseeing this difficulty, though the Bohr atom was as yet years in the future. He had an atomic concept of his own in mind at that early date, and pointed out that the distance between the particles constituting an atom must be thousands

[24] Kaufmann, *Gesell. Wiss. Göttingen*, Nov. 8, 1901; July 26, 1902; March 7, 1903.

of times the diameter of a particle. In consequence, said he, almost all the mass will originate where the lines have their greatest density, near each particle; and the particles are relatively so far from each other that the parts of the lines of force in their immediate neighborhood will have almost perfect freedom of orientation with the motion of the atom.[25]

This is a quantitative question; but it is clear that only under the most favorable conditions will we have a freedom of motion in the atom which approximates that around an isolated charge, and in consequence the electrical explanation of matter, on J. J. Thomson's theory, must be in the same degree approximate.

With the neutron conditions are more rigid. Assuming the neutron to consist of a proton and a negative electron, the union of these must be almost as close as possible, as the neutron, on modern theory, may form a constituent of an atomic nucleus. Here we are dealing not with atomic magnitudes but with subatomic dimensions, which is quite another thing. Freedom of motion of the lines of force in such a structure must be almost non-existent. And if we make the alternative assumption that the neutron is an independent, non-electrical entity, the electrical theory of matter must admit of an important exception.

But an electrical theory of matter to be acceptable must admit of no exceptions. It must obey the all or none principle. If it is approximate in even the slightest degree, we are confronted with the existence of two kinds of matter, ordinary and electrical, and we are violating the rule of simplicity in reasoning laid down by Newton.

But has there not been later evidence supporting this theory?

It has sometimes been said that Millikan's oil-drop experiments, by which he measured the charge on a single electron, prove the constancy of this charge, and hence the variability of the mass alone in Kaufmann's experiments. It is true that Millikan found that the charge on an ion *after it had been transferred to the oil-drop* was the same whatever the source of the original charge. Ions of different gases, unquestionably of different speeds, gave the same charge to the drop. But it is to be remembered that the measurement of this charge was made, not at the speed of the ion, but at that of the oil-drop, which was of the order of a few hundredths of a centimeter per second.

The special theory of relativity is sometimes quoted in support of the constant charge and variable mass. It is true that Einstein[26] in his original paper of 1905 gives a formula for the change of mass with the speed of a moving electron, which, like J. J. Thomson's formula, becomes infinite at the speed of light, and that he gives no similar formula for a change in the charge. It will be interesting for us to see how he obtained this result.

In section 10 of his paper Einstein derives the following formula for the x-component acceleration of a moving charged particle, together with formulas for the other components:

$$\frac{d^2x}{dt^2} = \frac{e}{m}\frac{1}{\beta^3}X$$

in which e is the charge on the particle, m its rest mass, X the component of the electric vector and β the familiar $1/\sqrt{1-v^2/c^2}$.

It is evident that the quantity e/m is altered by the factor $1/\beta^3$, but whether the charge or the mass or both are changed is not obvious. Einstein without comment assumes e to be constant and m to bear the full effect of the modifying factor, and on this basis derives his formula for the change of mass.

[25] J. J. Thomson, "Electricity and Matter," New York: Scribner's, p. 51, 1904.

[26] Einstein, *Annalen der Physik*, 17: 891, 1905.

This assumption, of course, was orthodox in 1905, but it is of interest to note that as a matter of logic the electrical theory of matter can claim no supporting evidence from the special theory of relativity.

On the basis of this result of Einstein's, Sommerfeld[27] introduced a modification into Bohr's theory of the atom. On Bohr's theory the hydrogen atom was regarded as consisting of a negative electron revolving in a Keplerian ellipse around a positively charged nucleus, the attraction between the two charges being balanced by the centrifugal force of the revolving electron. Sommerfeld (page 45) makes the orthodox assumption that the electrical charges remain constant, but that the mass of the revolving electron varies with its speed according to Einstein's formula. In consequence the mass of the electron fluctuates as it describes its orbit, being greatest at perihelion and least at aphelion, and its centrifugal force will vary slightly from that in a non-relativistic Keplerian ellipse. Because of this the orbit becomes an ellipse with a moving perihelion, like that of the planet Mercury. The effect of this will be to split up the spectral lines, producing what Sommerfeld called the relativistic fine structure.

This predicted effect has actually been found in the spectra of hydrogen and helium, the number of the component lines and their relative separation being in accordance with theory.

As to the value of this result as a confirmation of the electrical theory of matter, it is to be observed that Sommerfeld would have obtained exactly the same modification of the Keplerian ellipse if he had assumed the charge to decrease and the mass to remain constant, thereby disturbing the balance by reducing the centripetal attraction instead of increasing the centrifugal force.

[27] Sommerfeld, *Annalen der Physik*, 51: 1, 1916.

The logic of the whole situation is that the electrical theory of matter can claim no independent support from Millikan, Einstein or Sommerfeld. It rests for the present on J. J. Thomson's theory, and even this theory assumes tacitly that the charge is unaltered by the motion. It is remarkable that every one we have mentioned, from J. J. Thomson onward, when confronted with the necessity of making a choice, prefers to keep the charge constant and let the mass take the consequences, and this without comment or apology.

Of course, there must be a reason for this; and although it is explicitly stated by no writer that I have seen, the reason is doubtless to be found in a fundamental law of electricity, that of the conservation of electrical charge, with its corollary, the exact equivalence of positive and negative electricity. This law states that no one has ever produced the slightest trace of a positive charge without the simultaneous production of an equal and opposite negative charge somewhere in the neighborhood.

This law has been the subject of some very searching experiments. We may operate within a large conducting cube, such as was built by Faraday at the Royal Institution; perform within it all the usual electrical experiments, excite a glass tube by rubbing it with fur, draw sparks from an electrical machine, and yet a sensitive gold leaf electroscope connected to the cube will remain undisturbed. It seems impossible to create or destroy an electric charge without a compensating creation or destruction of an equivalent charge of the opposite sign.

And yet the era of thought which has not hesitated to question the conservation of energy can hardly be expected to respect this electrical principle; and in fact this law has been brought under fire from several quarters. If these points of order are sustained they will have an important bearing on future answers to the question "What is electricity?"

It is well to remember in this connection that all the experiments upon which is based the law of conservation of electric charge have started with neutral bodies. The glass tube and the fur were at first neutral, but exhibited equal and opposite charges after being rubbed together; the electrical machine was at first neutral, but on being operated its two sides became equally and oppositely charged.

Suppose a chemist should announce that as a result of the analysis of several thousand neutral salts he had come to the conclusion that acid and basic radicals existed in equal amounts in nature; we would likely think him ignorant of such syntheses as that of the acid radical cyanogen (CN) from its elements in the electric arc.

But is there any known electrical analogue of such a synthesis or its reverse dissociation?

No, nothing that we have so far been able to produce in the laboratory; yet if we imagine some race of children of the gods who could play with planets as we with pith balls, something of this kind might come to their notice.

Among the phenomena of atmospheric electricity there is an unsolved mystery. Many fruitless attempts have been made to explain it consistently with the principle of conservation of electrical charge. Continual failure has led more than one physicist to look for the explanation in a slight departure from this principle, and it has been shown that a departure so slight as to be beyond laboratory detection would yet, on the large scale, solve this mystery. The difficulty in question is to account for the negative charge of the earth.

For our earth is not a neutral body. Its entire surface is negatively charged to such an amount that there exists near the surface a potential gradient of 150 volts per meter. The conductivity of the atmosphere is small, but not zero; and because of this conductivity and the potential gradient there is a continual conduction of negative electricity away from the earth amounting, over the whole surface of the earth, to a current of about 1,000 amperes. Small as this may appear, it is sufficient to bring about a loss of 90 per cent. of the earth's charge in ten minutes if there were no means of replenishing the loss. The nature of this replenishment is the mystery referred to.

So great has been the difficulty of accounting for this replenishment that in 1916 G. C. Simpson,[28] now director of the British Meteorological Office, raised the question of a possible spontaneous production of a negative charge in the earth's interior, but offered no suggestion as to how this could be brought into line with existing theory.

In 1926 Swann,[29] who had worked unsuccessfully with the same problem, followed Simpson's lead, but chose the other alternative of a slight annihilation, or as he called it, death of positive electricity. He was able to bring this into connection with existing electrical theory by generalizing Maxwell's equations. His fundamental idea was that there might be a very slight difference in the properties and behavior of the two electricities. Here again we are reminded of the difference apparently found by Rupp.

Such a suggestion was not without precedent. Lorentz[30] in 1900 had postulated a difference between the attraction of unlike charges and the repulsion of like charges to account for another mystery—gravitation. It must be admitted that the accepted idea of the absolute equivalence and mirror-image

[28] G. C. Simpson, *Monthly Weather Review*, 44: 121, 1916.

[29] Swann, *Journal Franklin Institute*, 201: 143, 1926; *Phil. Mag.*, 3: 1088, 1927.

[30] Lorentz, Koninklijke Akademie van Wetenschappen te Amsterdam, *Proceedings of the Section of Sciences*, 2: 559, 1900.

character of the two electricities had weakened somewhat when such men as the director of the British Meteorological Office, the director of the Bartol Research Foundation and a Nobel prizeman could join in expressing doubt of its accuracy.[31]

Swann's theory of the maintenance of the earth's charge is, from the theoretical point of view, the most successful that has yet been advanced. He modifies the equations of Maxwell by introducing two small terms, amounting respectively to one part in 10^{28} and five parts in 10^{19} of the main term of the classical theory. These additional terms involve the acceleration and time rate of change of positive charge.

Swann assumed no similar terms for the negative charge, his idea being that there is a slight differential effect in behavior. For simplicity, therefore, he introduced a differential term applying only to positive electricity. This assumption enabled him to account for a slow death of positive electricity due to the centripetal acceleration produced by the earth's rotation.

To account for the known electrical facts, there is necessary an annihilation of less than one proton per cc per day, equivalent to a loss of 0.5 per cent. of the earth's mass in 10^{20} years. This would also account for as much of the earth's magnetic field as is symmetrical about the earth's axis, and would give the correct ratio for the magnetic fields of the earth and the sun. Moreover, no development of charge or magnetic field could be detected with a sphere of laboratory size rotating at the highest practicable speed. And finally, Swann's scheme is consistent with the special theory of relativity.

Whatever may be thought of Swann's fundamental assumption, it must be admitted that his theory is experiment-proof. Moreover, even though it should be definitely disproved, it would have the lasting merit of impressing upon us caution in extrapolating laboratory results to the cosmic scale.

The relations of newly discovered fact and existing theory are, as we have seen in this somewhat brief survey, rich in suggestion. Speculation is not dead, but sleeping. If the past is still an indication of the future, it will awake again to renewed activity, and when this occurs we will need a wide acquaintance with fact and a good sense of perspective to guide and direct future speculation on the question, "What is electricity?"

[31] Additional references: More, *Phil. Mag.*, 21: 196, 1911; Gleich, *Annalen der Physik*, 83: 247, 1927; W. Anderson, *ibid.*, 85: 404, 1928; A. Press, *Phil. Mag.*, 14: 758, November, 1932.

THE PROBLEM OF FARM TENANCY

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DURING the past half century, the increase of farm tenancy has been one of the undesirable and yet wide-spread characteristics of rural America. Only two generations ago we were at the heights of the homestead movement, which had as one of its fundamental aims the creation of an agriculture made up predominantly of small farm operators. To-day we find that half of our farm lands are operated by tenants, and nearly that large a percentage of our farmers rent all the land they farm.

By the homestead laws and legislation of earlier years, the development of family-sized farms owned by resident farm operators was encouraged and promoted. This was a wise and highly desirable feature of our land policy. Unfortunately, however, our land policies failed to safeguard the permanent ownership of family-sized farms by the actual operators who farmed them. The land speculator was a pernicious counterpart of our early land settlement activities. Along with the pioneer squatter and homesteader was the speculative "land grabber," into whose hands soon fell much of the best virgin soil of America.

The recent report of the Land Planning Committee of the National Resources Board declares: "The operation of farm land by the owner was no doubt the ideal of all who favored liberal land policies. European tenant-ridden countries were cited in contrast with America, where every man could sit under his *own* vine and fig tree. It is easy, therefore, to understand the feeling of consternation which prevailed when the census of 1880 revealed that over one fourth of our farmers were no longer owners but had somehow become tenants in spite of homestead and other liberal land laws." By 1930, about 53 per cent. of our farmers operated leased land, and 42 per cent. of them rented all the land which they operated. The forces of depression appear to have increased this proportion, so that to-day it is estimated that not less than 45 per cent. of all our farmers are tenants.

The consequences of the failure to safeguard the principle of farm ownership by the operator of the farm is emphasized by the rapid development of farm tenancy in the states most recently settled under the homestead system. In North Dakota, for instance, where a large percentage of the land was homesteaded in the latter part of the last century, over 34 per cent. of all farmers in the state are tenants. The same development occurred in South Dakota, where almost half the farmers are now tenants. In Oklahoma, one of the last states to be opened for settlement, about two thirds of all farms are now operated by tenant farmers.

Our federal reclamation policy was also urged as a means of creating farm homes operated by owners. Nevertheless, there was the same failure to safeguard the system against the land speculator and the absentee landlord. Consequently, we find that about 40 per cent. of the farms on federal reclamation projects are operated by tenants.

The growth of tenancy is all the more serious because in the main it has occurred on the better lands in each of the principal regions of the country. In some of the best prairie counties of Illinois, for instance, you will find 70 to 80 per cent. of the farms operated by tenants. Tenancy is closely associated with

the specialized production of the major cash crops, the surplus of which has been troubling this country for more than a decade. Because it is associated with commercial farming and specialized crop production it is closely associated with and related to that other great evil of our land system—land speculation.

The fact that the tenant farmer has been intrusted with some of the best soils of the nation is especially serious because a large proportion of our tenants have little permanent interest in soil conservation. The average period of occupancy by tenants is only a little more than four years. Since few tenant contracts provide compensation for improvements made by the tenant and since both landlord and tenant are usually interested in the production of cash crops, it follows that in general tenancy is largely responsible for the serious and progressive depletion of soil fertility. We can hardly deal fundamentally with erosion and other types of soil wastage until we bring about a change in the relationship of tenant farmers to the lands they operate.

Some of the worst characteristics of the American tenancy system are found in the South. A great many people think nearly all southern tenants are Negroes. On the contrary, of the 1,800,000 tenants and croppers reported in the sixteen southern states by the 1930 census, only 700,000, or less than 40 per cent., were Negroes. Notwithstanding the tremendous increase in tenancy which occurred in the South between 1920 and 1930, all the gain was brought about by an increase in the number of white tenants. In fact, there was a slight decrease in the number of Negro tenants and croppers between 1920 and 1930, but there was a gain of 69 per cent. in the number of white croppers during that decade. A large number of southern owners and share tenants, particularly white owners and tenants, were forced to revert to the propertyless status of croppers by the agricultural depression which started with the fall of prices in 1920.

The disintegration of the farm system in the South, particularly the plantation phase, has become progressively more rapid since the world war. Factors which contribute to this include the increased mechanization of cotton production, especially in the western areas and in the alluvial portions of the lower Mississippi Valley; adverse influence on older areas of the competition in cotton production by the newer western areas; soil erosion and depletion of soil fertility from the one-crop system; the gradual depletion of timber resources which formerly supplied employment and income in many areas; a series of price crises since the world war that impaired the ability of many landowners, supply merchants and plantation operators to supply their tenants, and the pull of industrial employment which attracted labor from the South until the advent of the depression in 1929.

Since the depression, the displacement of Southern tenants and the increase in the number of rural "squatters" has been sharply increased. This was a condition with which the AAA was confronted when the first program was inaugurated to increase cotton income in 1933. We recognize that the operation of the cotton program has probably added to the immediate difficulties, just as relief policies have injected additional complications into the usual tenant and farm labor relationships. It is inevitable in a period of emergency that such disturbances should occur. But we should realize that neither the AAA programs nor any relief program can really come to grips with the fundamentals of these conditions. At best, anything we might do either through the AAA or relief would be temporary palliatives.

The present conditions, particularly

in the South, provide fertile soil for Communist and Socialist agitators. I do not like the bitterness that is aroused by this sort of agitation, but I realize that the cure is not forced violence or oppressive legislation to curb these activities but rather to give these dispossessed people a stake in the social system. The American way to preserve the traditional order is to provide these refugees of the economic system with an opportunity to build and develop their own homes and to live on the land which they may call their own.

In the South, as in many other regions, the real problem is to reassociate labor, land and capital in such manner as to enable the people to maintain a better standard of living than formerly under more wholesome conditions of operation both for the people and the land.

We have been talking about the evils of farm tenancy in this country for a great many years. It is high time that America faced her tenant situation openly, and pursued a vigorous policy of improvement. Studies made by the Department of Agriculture, state experiment stations and other research agencies have repeatedly shown that in communities where tenancy is extensive there is an unusual degree of rural instability and lack of a well-knit social life. It is almost impossible for tenant families who move from place to place every two or three years to participate in the activities of schools, churches and other similar rural institutions.

I do not mean to imply that all tenant farmers are poor farmers or that all of them are migratory and unstable. Perhaps the best type of tenancy in America is that which arises when a farmer retires and rents his farm to a son, a son-in-law or some other relative. In such cases the owner usually lives near-by and both he and his tenant relative are interested in the upkeep of the property. The owner continues to exercise considerable supervision. The tenant, after his period of apprenticeship, is likely to inherit the property or acquire it through some other family arrangement. This kind of relationship is to be found on about 19 per cent. of the farms of the United States, and it is especially prevalent in the Corn Belt and dairy regions. In one or two states as many as two fifths of the tenants are related to the landowners. There are also many other landlords not related to tenants who live near their farms and exercise a wholesome influence on the system of farm management.

Nevertheless, even in the Northern States a great deal of tenancy is characterized by instability of occupancy, absentee landlordism, soil exploitation and lack of identification of the tenant with community life.

It seems to me that it will be virtually impossible for America to develop a rural civilization which affords security, opportunity and a fully abundant life for our rural people unless she acts to convert tenants of this sort into owner farmers. It is extremely unlikely that a satisfactory and stable rural civilization can be developed in communities where the land is owned by absentee landlords interested primarily in profit and farmed by tenants who are willing, if not encouraged, to mine the soil and allow the buildings to decay, with the thought that they can move on to a different farm every two or three years.

If I understand correctly the general philosophy underlying the bill introduced by Senator Bankhead to create the Farm Tenant Homes Corporation, it is aimed at going back to the old principles, intended but not realized in our early land policy, of trying to get the good farm land of America into the hands of owner-operators who live on family-sized farms, but with proper safeguards to prevent the land from again becoming a football of speculation. I am confident

that the provisions of this bill, if it is enacted into law, can be administered in such a way as to bring greater individual opportunity to hundreds of thousands of our tenant operators; check the growth of rural tenancy in this country; and bring much greater stability and security to thousands of farm communities. Moreover, it would be of substantial aid in dealing with our problem of surplus cash crops. Our recent experiences have shown that a reduction of acreage in a tenant community tends to create agricultural unemployment, with some of the evils characteristic of urban unemployment. However, in communities where practically all farms are operated by owners, the acreage reduction programs have brought about a greater diversification of farming, with a resulting higher standard of living, and have aided in increasing soil fertility.

No better method of aiding our tenant farmers can be undertaken than to give them a secure form of tenure on a family-sized farm; aid them in carrying out a farm and home management program that will yield a reasonable cash income; and, at the same time, create a farm and home unit as a permanent, desirable and secure place to live and rear their children.

It is imperative that the administration of a bill so far-sighted and socially desirable as this Bankhead bill be carried out in accordance with sound principles of farming and in the light of the best experience in dealing with rural problems. I take it that the main purpose of the bill is not to make available a large sum of liberal credit to be promiscuously used in aiding tenants to purchase farms, without any thought as to the resulting consequences of their newly acquired ownership. To transform some of our inexperienced and undesirable rural tenants into immediate owners, by the simple expedient of loaning them substantial amounts of money on very liberal terms, might create more social problems than it solves. On the other hand, by following a sane and conservative program for aiding desirable tenants in becoming owners, and by helping the inexperienced ones to follow sound farm management practices, we shall be able to aid them in buying a farm which they can retain as a permanent home.

For many years, practically all European countries have had policies for aiding tenant farmers to become landowners. About 60 years ago, Ireland entered upon a program of abolishing her tenant system, which was one of the most abominable that has ever developed in the Western world. By instigating an active policy, in which the part played by the government was to buy large estates and resell them to tenant operators on a long-time payment plan with low rates of interest, Ireland was transformed from an island of poverty-stricken tenants into a nation of independent farm-owners. The resulting social and economic gains have been enormous, and the losses to the government have been negligible. The customary rent paid by the Irish tenant was simply transferred into a payment on his farm, to which he gained title only after the last payment was made. In a similar manner, Denmark, Finland, Germany and other European countries have made government loans available to agricultural tenants as an aid in purchasing farms.

England is practically the only country in the Old World which has not had an active governmental policy of aiding tenants to become owners. She has accepted tenancy as a permanent institution, and developed measures to alleviate its customary evils. For many years there have been laws in England which provide for fair rents, a long and stable period of occupancy by tenants, and which compel landlords to compensate tenants at the termination of the tenancy

for improvements of the land and buildings. The compensation paid to tenants by landlords for building up the soil and improving buildings has been an important factor in maintaining a stable agricultural economy in that country.

It may be argued by many people in this country that to aid a tenant in becoming an owner on a shoe-string of credit is socially undesirable and economically unsound. Without governmental assistance, however, it is often extremely difficult for tenants to obtain holdings of the proper size to fit their ability and family labor supply. Moreover, it has been virtually impossible for more than a decade for many of our energetic and ambitious farm boys to acquire capital sufficient for the customary down-payment on a good farm. Many tenants with years of farm experience have been earning such a small margin, after they paid their rent to the landlord, that they were virtually forced to continue through life as tenant operators. The percentage of tenants who are more than 55 years old has been increasing in this country for several decades. Now we have about 375,000 who are over 55 years of age. Many of these people have struggled toward ownership for years, and yet in their old age have no home of their own and no more security than when they started as farm laborers.

An active government program aimed at making owners out of desirable tenants, through a system of long-term loans which can be repaid by taking the ordinary rent as payments toward the ownership of a farm, is a thoroughly sound and justifiable procedure for creating greater security and more desirable homes for our rural tenant population. During the period when the purchasers are slowly creating an equity in the farms they operate they will have all the security of an owner and should develop a real and lasting interest in maintaining their homes and permanently participating in the social life of their communities.

In short, I believe we need legislation which has as its aim the creation of a substantial group of farm-owners out of our present tenant class. I know of no better means of reconstructing our agriculture on a thoroughly sound and permanently desirable basis than to make as its foundation the family-sized, owner-operated farm.

THE LIFE IN THE SOIL

By CHARLES THOM

PRINCIPAL MYCOLOGIST, DIVISION OF SOIL MICROBIOLOGY, BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

In March and April the urge to plant something strikes some fifty million Americans. It is the same urge, whether I plant three seeds in a tomato can or you plant a thousand acres of wheat. We put our seeds into the soil and watch them grow. But how much thought do we give to the soil in which they grow? Is it fertile or sterile? Is it an inert mass, or is it teeming with life?

Get down and look closely at the surface of your patch of soil. You saw no weed seeds when you dug it, but at least a half dozen weeds are coming up for every seed you planted. Perhaps a cluster of moss plants appears. Then you see a patch of green or blue-green right on the surface—some alga is growing freely on the moist earth. Traces of last year's crop—decaying leaves, grass or weed stems are slimy with bacteria or show patches of black or brown or bright-colored mold.

Then you see a hole or two, suggestive of some animal which prefers darkness, at least when we are around. Thrust a trowel under one of the young plants, lift it out unbroken and examine the ball of earth about its roots. If you act quickly you may catch a wriggling earthworm or a grub or two, hastening from harm's way into unbroken soil; half a dozen other creeping or scurrying animals are trying to escape. Then look a bit closer, or drop a lump of earth into water, and examine it closely with a hand lens. Another series of worm-like things just about at the limit of visibility to the naked eye pass in review.

These visible forms are gross destroyers of plant and animal material; earthworms and insects swallow and digest part of this food. They drag some of it into their burrows. Some kinds feed at the surface and only retreat below for protection. Others work entirely below ground. Their holes ramify through the top soil and go deep enough to ensure contact always with moist earth. Such holes act as ventilating flues which carry air in and gases out. Rain water floods them and drives the owners to the surface, where the birds get some of them, while multitudes dry up and lose their lives. Some of these animals are definitely useful, some are definitely destructive. We need to know them therefore and to know for any particular soil what types to encourage and what types to destroy. But we have only begun when we talk of the bugs and worms which we can see with the naked eye. We pass our seedlings over to the laboratory.

The microbiologist uses his microscope and his staining materials. He washes the dirt off young roots and examines their tips—each rootlet and each root hair is fringed with microorganisms, including bacteria, yeasts, molds and amoebae. Life and growth are transient things: The active work of the root is done by delicate living cells in direct contact with earth. These cover the freshest and newest inch or two of each rootlet. Only a little way back from the very growing point, cells which have done their work are already dead and are filled with bacteria and mold threads; they are well along in the process of decay. Back of that, the root becomes a hold-fast to keep the plant secure, and conducting tissue to link the green parts above with a complex collecting system of rootlets in the soil, which

gather its water and plant food. All around these complex branching systems swarms of microorganisms line every pore of the soil and attack every waste or worthless bit of vegetable matter. Such organisms form a total of many millions to the average teaspoonful.

Rootlets penetrate every clod of the surface soil and are readily observed in the deeper layers. Some roots can be followed down several feet. Three feet down on a roadside bank, we found a hole about an inch in diameter. Examination showed a lining of bark, out of which a large root had rotted away—microorganisms had gone right along with the root, and destroyed it when the tree was cut down to build a road.

In my laboratory, I have a chunk of Virginia clay, painstakingly dug by a chemist friend of mine to show how a root had bored its way through a mass of hardpan situated about 3 feet down in the earth. That layer was so hard and dense as to be almost impervious to water, yet the root got through it. He showed other masses with the roots still in them. This root had finally died, and bacteria had rotted it away, but the walls of the hole were discolored by bacterial slime and soil solution that had followed the root channel. In other blocks he showed how several generations of roots had gone through hardpan into the earth beneath through a single channel. Such root channels are factors in the distribution of water and microorganisms into the deeper layers of the earth.

This picture of soil population relations is further complicated if we remember that there are a thousand and more varieties of soil in the United States and each presents somewhat different conditions for growth; hence we must expect to find a multitude of variations in the proportional number of various elements in the population. As a conspicuous example of contrasts, I have seen places where one could pick up a quart of earthworms in a very small area after a rain, while a soil man working in one county in Kentucky declared he could not find enough worms in the whole county to go fishing once.

The distribution of microorganisms in relation to the soil particles is also important. To get a picture of this distribution some of us stopped in a cut along the highway and broke fresh vertical slices from the top of the bank. Then the inventor who went with us set up a microscope designed to examine the cut face of the soil. By a special device he threw a strong light into each little spot at which his microscope pointed, then each of us looked into the broken face of the soil. Such a cut is not smooth; the soil is composed of innumerable particles of varying size and shape and hardness, packed together, but with cracks or pores among them. Some of those particles are shapeless—amorphic, some are grains of sand or crystals with smooth or broken facets; the whole forms a weird mixture of the flotsam and jetsam of ages of rock disintegration and of life activities. We focussed our microscope upon some of the grains of sand. Each facet was partly masked or smeared with translucent material; the chemists call it colloidal slime. We looked deeply as we could into the pores, and saw, not sharp angular cracks between clean sand particles, but channels winding and twisting among grains of soil smeared over with slime and cemented together by it.

Then we set our microscope upon a stump, pried out an unbroken clod and put it under the lens, arranging a mirror to throw a beam of sunlight on the spot at which the microscope was pointed. Down in the pores of the soil we could see bits of mold protruding, patches of varicolored growth, and here and there some minute animal retreating from our unwelcome intrusion.

Next we picked out some of the smallest and brightest of the sand grains seen,

rolled them upon a glass plate, stained them and looked at them with the microscope. Their surfaces were dotted with microscopic masses or colonies of bacteria or yeast-like organisms, and often streaked by threads of mold. Tufts of mold stuck out into the open spaces between the grains. Cultures from this type of crystal show thousands of colonies of a weird mixture of microscopic living things.

What are these organisms? Whence do they come? And what do they do where we find them? Identification of kinds or species produces a varied list of bacteria, molds, protozoa, algae and microscopic animals of higher groups. Thousands of species of molds and bacteria can be found above ground. They are in or on everything; they infect; they rot; they ferment. Sooner or later all of them are carried into the soil on waste materials. Many of them perish there, but if one hunts long enough, widely enough and carefully enough, great numbers of them can be recovered and related to their source.

These organisms carried in from above are not the whole population, for there are a myriad more already in the soil—kinds which are at home there. These are found in every soil—not just in a few places.

Some review of the everyday business of this complex soil population may be presented. In all ages, the worn-out, the worthless and the offensive have been dumped upon the ground or buried; nearly all disappear. We commonly say that some things rot, and others corrode. The soil is the universal leveller. The monarch of the forest, the moss in the cleft of the rock, the mastodon and the microbe have played their temporary parts; their remains went back to the general supply of raw materials, sooner or later to be used again. How these complex structures went back to simple forms, what agents were active in the process and what chemical changes were involved are only partly answered.

If we take a sample from unplowed earth from a reasonably fertile field and subject it to the examination of the bacteriological laboratory, it will show roughly 20 to 40 million microorganisms to the gram. When put into a testing chamber, it will give off measurable amounts of carbon dioxide. The organisms are not only present, but they are active. If we test fresh samples at regular intervals we will find changes in numbers, changes in group representation, and changes in rate of carbon dioxide evolution, but as long as the field remains unplowed, a general level of activity is maintained; the changes are minor. A kind of biological balance has been reached, based upon the growth conditions presented.

If we plow and plant that ground, the whole situation changes; the top six inches of soil are broken up; last year's plant remains and the top soil with its myriads of organisms are turned under or mixed with fresh soil; air is stirred in. The top six inches are now loose or porous instead of firm. Then we find that myriads of microorganisms that had lain quiescent in the deeper layers spring into activity.

If there be one feature of a microbic population more striking than any other, it is this capacity for sudden and tremendous increase in numbers and biochemical activity when conditions become favorable. A crop of clover or vetch plowed under begins quickly to decay. The number of microorganisms found in the decaying mass may reach billions within a week, then drop back more or less quickly toward some normal figure. The slimy residues produced help hold the soil particles together against wind and water. If large amounts of material were plowed under, totals of population in the whole plowed mass may remain two to several times higher than before. Cultivation keeps the ground stirred, keeps up aeration and favors the maintenance of this increased activity. If a sample is put

into the test chamber at the height of such activity, the rate of carbon dioxide production suggests a fire; quickly fermentable matter rapidly disappears; the excess of carbon dioxide escapes into the air, where most of it serves no immediate purpose. These activities are definitely destructive.

Under intensive cultivation, as in continuous cereal farming, reserves of soil organic matter are attacked; supplies of nitrogen are reduced. As long as such reserves remain ample, large crops can be grown. But if we continue this process year after year without replacing material destroyed by such activity, the supplies stored in the original soil in past ages can be so depleted as to interfere with crop production.

This is exactly what happened in our prairie states. I can remember when many farmers believed fertilizers unnecessary. I have seen manure dumped into the river. Out in Nebraska and Kansas they have measured their lost fertility in cultivated areas against what they still find in unbroken prairies. From some of those farms half the material stored up in ages past is gone in a single generation of grain farming. Such losses eventually upset the balance and troubles begin to appear. These take various forms, some of which may be mentioned.

Down in the hotter sections of the Southwest, cotton root-rot has long taken a heavy toll—forty million dollars was the penalty reported last year. King, of the Bureau of Plant Industry, working in Arizona, found that where he put a lot of stable manure or farm waste in a deep furrow below his cotton, the disease was controlled. Over in Texas, another group of workers broke up the subsoil and stirred in a crop of sorghum with the same result. In the prairie states, wheat has been pestered by a root-rot fungus so mean that men call it "take-all"—it leaves the farmer nothing. Fellows, another Bureau man, seems to be proving that mixing hen manure into the soil controls the "take-all" fungus.

What do these observations mean? These destroying fungi are not new organisms; they were there before the white man came. But the land was in native grasses; a natural balance seemed to hold between green plants, bacteria, fungi and all the rest. Then man came along with extensive farming methods; he destroyed the original sod; he speeded up some processes; he depressed others; as a result some organisms run riot because those which should hold them in check are suppressed.

These are but a few illustrations. Similar situations can be found with endless variation if you go out and look for them. They are brought out here as evidence that while plowing and planting, fertilizing and hoeing are directed at flowers or vegetables, orchard trees or field crops, they also affect a world of microscopic life unseen but not unimportant to the farmer.

Your patch of soil and mine present their separate problems. Each has its peculiar natural population above ground and below, but when we decide to grow one particular choice of crop we must survey the whole problem if we are to get the best out of our soil. We need to know the kind of fertilizer and cultivation required by the particular crop; we must give due heed to the combination of mineral and organic materials which make up the particular soil; but we need also to see in that soil the home of a complex micropopulation, among which are species which may help or injure that crop and which must be handled correctly, if we are to continue to get the largest return from our investment.

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THE STORY OF MAN

By HENRY FIELD

FIELD MUSEUM OF NATURAL HISTORY

THE story of man—past, present and future—concerns every living person. Man's past, however, is a much longer story than the average person appreciates. Many people realize that in order to understand the present and plan intelligently for the future we must have some knowledge of the past. But those same people may turn to ancient Egypt, to Greece and Rome, to William the Conqueror and Alexander the Great, and feel that they are going back to the beginnings of history.

Man's struggles and victories began hundreds of thousands of years before Alexander undertook his brave expeditions—and those struggles were against greater odds, those victories more inspiring, than any man has known since the time that history was first written.

Let us review in outline the main features in the dramatic story of man during the past million years. In passing from the darkness of our knowledge of the first men down to the dawn of history, we are continually aware of the limitations of available information. We owe an eternal debt of gratitude, however, to the scientists who have contributed fragmentary pages to the book of knowledge, which is the story of man.

Who was the first man, and where did he come from? It is difficult to trace the unwritten record of man, since many of the details lie buried in the earth or are lost beyond recall. During the past few centuries it was believed that the world was created in the year 4004 B.C. and that man was the result of special creation. At the close of the first third of the twentieth century scientific workers have shown absolute proof that hundreds of millions of years passed before any animal that could definitely be recognized as human had evolved upon the earth. Study of both living and fossil forms reveals the fact that a labored evolutionary progress from simple one-celled organisms to many-celled, from fish to amphibians, from reptiles to birds and mammals, was necessary to produce the most advanced form—man.

Branching off from the main primate stock several million years ago, our ancestors possessed many physical characteristics in common with the anthropoid apes. As time passed, the gap between the two branches grew ever wider. We do not know just when or where the first humans evolved, but the evidence that man did develop in such a manner is undeniable, and gradually the facts are being pieced together to form an increasingly clear picture.

On the northern border of Europe—in England— and on the eastern fringe of Asia—near Peiping—the earliest traces of man have been found. Primitive evidence has also been unearthed in Africa; so that even hundreds of thousands of years ago mankind had spread far and wide. The data, consisting of fragmentary human remains, stone tools, animal bones and the charcoal of hearth fires, are still too few to draw any but the crudest picture of the earliest members of the human race. There is abundant evidence of man's existence a quarter of a million years ago, however, in western Europe. The climate was mild. The elephant, rhinoceros and hippopotamus were the dominant forms of

animal life. The man of that period must have been rugged, powerful-jawed and ferocious in appearance. Small in numbers and physically weak in comparison with the creatures which surrounded them, the earliest hunters were forced to use ingenuity and their powers of reason in order to maintain themselves in a hostile world. They had knowledge of fire, which enabled them to keep off marauding animals at night. They developed the art of flaking flint to a relatively high degree of perfection. With only wooden spears and handaxes for weapons, however, they must have often been more hunted than hunter. It is interesting to recall that these primitive hunters—the Chelleans, as they have been named—could walk from France to England, because at that time the English Channel had not been cut by the sea.

In Field Museum eight large dioramas, with figures realistically modeled by Frederick Blaschke and backgrounds painted by Charles A. Corwin, portray graphically the main stages of man's development. The first diorama is a Chellean scene in northern France some 250,000 years ago. In the foreground, squatting beside a fire in the shelter of a large rock, are two hunters, one of whom is chipping a flint handaxe preparatory to the hunt on the morrow. In the distance is a meandering river, and on the opposite bank three elephants are frightened from their watering place by the smell of the dense smoke of the fire. Farther upstream a hippopotamus can be seen on the bank. Near the skyline, a magnificent stag, anxiously watching the flickering light, protects his hinds from the scent of danger. Stealing through the underbrush, a pack of wolves is barely distinguishable. This moonlight scene recalls vividly man's plight, as well as his strength, some quarter of a million years ago.

Development during the following tens of thousands of years was extremely slow. A long interval of time found Europe under the effects of a cold climate, the approximate date being 50,000 years ago. The mammoth, reindeer and other cold-loving animals wandered over western Europe. Then Neanderthal man—a new race—made his first appearance. He was about five feet four inches tall, thickset, with a large head and short limbs. The head, thrown slightly forward, was carried in that position by strong neck muscles. To our eyes his face would have had a fierce expression, emphasized by the enormous brow-ridges, small, round eyes and broad, flat nose. It is interesting to note that the lobe of the brain associated with the power of speech was little developed, as compared with that of his modern brother.

Neanderthal man lived in caves or rock-shelters for warmth and safety. A fire, built near the entrance, formed excellent protection against cave-lions, bears, hyenas and other animals. Neanderthal man was probably the first to seize a woman and protect her from animals and other men. This was the beginning of family life—a great step forward!

The struggle for existence was hard, and there was no time for relaxation and the development of the artistic sense. Stone and bone tools show marked improvement in technique. One Neanderthal ceremonial burial suggests a reverence for the departed and a belief in a future life, because a stone weapon was found in the hand of the skeleton, and apparently fresh meat had been placed inside the grave. In another locality charred bones of human beings suggest cannibalism.

The hunters of this period developed the use of fire, a new variety of flint and quartzite implements, the beginning of family life, and they believed in a future existence. Considering these important advances, we must recall with pride the struggles of our Neanderthal predeces-

sors against an inhospitable climate and savage animals.

We now pass rapidly over the next 20,000 years, and find Europe still under the influence of a bitterly cold climate. A new race, called the Crô-Magnons, swept into Europe from the plains of Asia. They were of magnificent physique, tall in stature, with a large cranial capacity. During this time the struggle for food became less intense, due to a more abundant supply. As a direct result there was time for the development of a latent artistic sense.

Here was the dawn of art. In their cave-dwellings the Crô-Magnons began to adorn the walls with engravings and paintings by means of a flint tool or by application of some colored pigment of red, yellow, black or white. They made accurate reproductions of the animals which they hunted, and occasionally they represented human beings in the innermost recesses of the caves. Personal ornament was also a new development. Necklaces of reindeer teeth, sea shells or fish vertebrae were worn. Ivory beads fashioned from the tusk of a mammoth probably corresponded in value to modern pearls. We find their dead buried with their finest shell ornaments, their most useful tools and weapons, presumably to make an imposing appearance in the new life beyond the grave. In several caves we find the imprint of a red hand on the wall, sometimes with the fingers missing. The motive which prompted this terrible mutilation of the hand is unknown, but we can give some modern parallel instances. For example, in the early nineteenth century travelers among the Bushmen in South Africa recorded that the women cut off their little fingers with stone knives as a sign of mourning. This was to ensure a long career of feasting after death or a safe passage to the next world. Among other tribes, this mutilation was a sign of caste, a tribal mark, or a cure for sickness. Catlin described the removal of the forefinger of the left hand during the initiation ceremony of the Mandan Indians. On the island of Tonga in the Pacific area Captain Cook reported that fingers were sacrificed to propitiate the god Atoa.

At the close of this period the climate grew still colder. Horses and wild reindeer were the chief sources of food supply.

Let us visit one of those caves in southwestern France to examine some of the famous cave paintings. Cave equipment, such as matches, candles, acetylene lamps, ropes and rope ladders, are carried to the mouth of the cave by guides. The lamps are lit and in single file we enter the dark mouth of the cave. It is relatively easy to walk the first few hundred feet. The cave walls are damp and there is a constant drip of water from the roof. The men in front are silhouetted against their swinging lamps and their echoing voices sound weird and eerie. Traveling becomes increasingly difficult and progress slower as we slip and slide on the wet floor. There are places where a rope is necessary to ascend the steep and narrow parts of the cave. By the light of our candles the beautiful stalactite curtains appear majestic. Finally we reach a rock gallery where, in the flickering light, we see the impressive engraving of animals made by prehistoric man many thousands of years ago. It is almost certain that these paintings were inspired by some magico-religious motive. This may be illustrated by the following example: A hunter is going to seek reindeer tomorrow. Food has been scarce and his family is hungry. After dark he goes to the medicine man of his tribe, who leads him into the cave, which fills him with awe. After a long, perilous climb, during which the sound of running water and strange echoes have duly impressed the hunter with the sanctity of his surroundings and the fearlessness of his leader and master, they reach the

innermost chamber. Here the medicine man makes incantations before the picture of a reindeer painted on the wall. To the primitive mind the spirit of the living animal is embodied in the painting. The medicine man therefore has power over the wild reindeer, a power which he transfers to the hunter by means of ritualistic incantations. Next day the hunter goes out with renewed confidence and is successful, as the medicine man has predicted.

We must pass from the development of an artistic sense and appreciation to the next stage, where the dog first became man's faithful friend at home and ally in the chase. The domestication of animals had begun.

Early Neolithic or New Stone Age times witnessed the first practice of agriculture and the manufacture of pottery, probably by the women. The domestication of animals and the cultivation of plants made settled community life possible. Without these epoch-making developments some ten thousand years ago there could be no great cities. The Neolithic hunters also learned to grind and polish their stone tools. Then came the discovery of the use of metals. First copper, then bronze, iron and steel—the age in which we now live.

We must now focus our attention on part of the "Fertile Crescent," formerly known as Mesopotamia—the land of the Twin Rivers, the Tigris and the Euphrates. The evidence obtained by three Field Museum North Arabian Desert Expeditions, of which I was leader, indicate that some six or seven thousand years ago the climate of the Near East changed. I believe that the inhabitants of what is now the North Arabian or Syrian Desert were forced by lack of water to become nomads, as are the Beduins to-day; to move westward to the pleasant, watered valley of the Nile, or eastward to the fertile alluvial plain beside the banks of the Euphrates and Tigris Rivers. Under these favorable conditions civilization began. The Field Museum-Oxford University Joint Expedition, excavating at Kish near Babylon, discovered the earliest known tablet—six thousand years old—bearing incised pictographic symbols. There was the beginning of the written record—writing. The oldest wheeled vehicle in the world—a four-wheeled chariot—was also unearthed in a special tomb among the ruins of mud-brick houses and sacred buildings. Evidence of the great deluge—the Flood of Noah—was revealed. Once again scientific research confirms the greatest written word—the Bible. The great temple of worship built by Nebuchadnezzar came to light, to bear silent yet eloquent testimony to the attainments of these makers of history.

In Egypt a different form of civilization was progressing slowly. The story of everyday life in ancient times beside the banks of the Nile has been revealed by the patient and careful study of the archeologist. The great pyramid of Cheops, the Sphinx with its age-old riddle still unsolved, the magnificent stone monuments at Luxor, Abu Simbel and other ancient sites create an inspiring picture of the advanced cultural development of the Egypt of their time.

As we rapidly review the historical period, we recall the great civilizations of classical Greece and Rome and their direct contributions to the thought, word and deed of the twentieth century. In other parts of the world, in China, India and Persia, progress was being made along different lines. Then from the Birth of Christ, until one hundred years ago, the story takes definite shape, in which certain makers of history stand out in bold relief. The last hundred years begin with the great industrial revolution and conclude with the vast modern economic upheavals of world-wide scope. The age of steel brings rapid transportation and communication—speed, speed, speed—wheels of industry spin so fast that western civilization

has become giddy with speed and power. Labor-saving devices and time-saving machines rotate at high speed. What do we do with the time thus saved?

The nation must learn to adjust itself to this added leisure—this time on our hands. Education in its widest aspects is the real solution to this vital problem. If, in our leisure time, we can but realize with an ever-widening knowledge and maturer outlook that in spite of most divergent types all human beings are alike deep under the skin, then machinery has freed us for a worthy purpose. The superb sculptures of racial types by Malvina Hoffman in Field Museum demonstrate wide variations of Caucasian, Asiatic and Negro; but there is a fundamental unity of mankind.

The course of future events can not be predicted. Six thousand years of civilization do not seem to have been sufficient to check the instincts of fear and greed. But, let me say in conclusion, we can recall with pride the struggles of mankind during the past million years. This will give us courage for the future.

WHY TAKE THE SUN FOR GRANTED?

By Dr. DONALD H. MENZEL

HARVARD COLLEGE OBSERVATORY

WHY is it that almost every one takes fresh air and sunshine for granted? The depression may have partially destroyed faith in the old axiom that the world owes one a living. But it has not diminished the daily supply of breathing material, and the good old ultra-violet rays appear to be about as capable of producing a painful sunburn as in the hectic days of 1929. Every filling station advertises "Free Air." The public accepts both air and sunshine as "free." There is a general supposition that they have always been and always will be "free"—whether the date is 1,000,000 B.C., 1935 or 1,000,000,000 A.D. I propound the question: "Have we the right to take the sun for granted?"

As we look back over history we find evidence that men did not always have our present child-like faith in to-morrow's sunrise or in the return of summer. Certain tribes had special priests, whose duty it was to offer sacrifices to the sun-god who, angry at mankind, retreated southward in the fall, punishing the people with bitter weather. Some of the priests, no doubt, sincerely believed that the return of spring was due solely to their efforts. Others may have been skeptical. If so, their position was not dissimilar to that of the crying child who, when asked the reason for her tears, replied that she wanted to go to the movies. "But," objected the kindly inquirer, "do your parents ever take you to the movies when you cry like that?" To which the child replied, "Sometimes they do and sometimes they don't, but it ain't no trouble to cry."

What would be your emotions if a radio announcer were to interrupt your favorite program with this report: "Ladies and gentlemen,—we have just received word that the sun has gone out!" Just think what such a catastrophe would mean! That to-morrow would be dawnless! That the earth would henceforth be doomed to perpetual darkness! I hasten to assure you that the sun was shining when I entered this radio station and I have reasonable confidence that it is still shining, though I can not absolutely guarantee it because this broadcast room has no windows—and I am sure that the sun is not infallible.

What if the sun were really to go out!

Picture the confusion! How rapidly would nations forget their petty troubles and put their shoulders to the wheel in a valiant effort to save themselves! They would have to move swiftly. In the course of a few sunless days summer would change to winter. Snow would fall in the darkness. Lakes and oceans would freeze. Food and fuel would rapidly disappear and civilization would be destroyed in a few months at best. Eventually the atmosphere would condense, liquefy and freeze to entomb the entire earth with a thirty-foot casing of solid air. What is the chance that such a catastrophe may happen to us? Let us explore the sun and try to find out what it is made of and what makes it go. Perhaps we shall find an answer to our question.

The sun is a star, a great hot ball of gas. And, conversely, stars are suns. The other stars are faint only because they are millions of times more distant than our sun. I wonder how many of you have ever seen the sun. Really seen it, I mean. Of course every one is conscious of the fact that somewhere in the sky there is a dazzling blur that hurts your eyes when you look at it by accident. You may have seen the sun's disk late in the afternoon or early in the morning, when its light was greatly dimmed by haze. Or perhaps you saw it through smoked glasses when you were watching the last eclipse. A good way to see the sun, and in its natural colors, is to make a very tiny hole in a visiting card and cautiously examine the sun through this.

Now let us journey sunwards. By the time we reach Mercury, the innermost planet, we shall have to use a five-cent piece for a sun shade. Though this is not very large, the sun's increasing nearness is clearly evident by the rising temperature. Our thermometer reads over 600° Fahrenheit. We continue our journey until the sun fills more than half the sky, where it will take something even larger than a wash-tub to shield us from the heat radiated by this gigantic furnace. At this point we are less than 1,000,000 miles from the face of the sun—a hundred times closer than we were at the start of our journey. Our thermometer reads 5000° F., and we deduce that it would read 11,000° F. at the solar surface.

The sun looks like a great pot of boiling lava, though 11,000° is too high a temperature for any substance to exist in either the solid or in the liquid state. Hence, all that surface is gaseous! The sun is covered with a multitude of flaming gas-jets—fountains of fire that extend upwards sometimes thousands of miles. Yet it is not real flame in the sense that something is actually burning there. For the sun is too hot to burn. If we could convey to the sun great quantities of the ordinary products of combustion—carbon dioxide, smoke and water vapor—we should see the stuff unburn before our eyes. The carbon dioxide would break up into gaseous carbon and gaseous oxygen. Then, if we could separate these two substances, and transport them back to the earth, we should be able to heat our houses next winter with the coal we burned last winter.

The outer layers of the sun are partially transparent, which calls to mind the earth's atmosphere. But there the analogy stops. In the solar atmosphere gales of a thousand miles an hour and sun-spot whirlwinds even more violent are frequent. The fiery gases consist not only of oxygen and nitrogen, the familiar constituents of ordinary air, but also of iron, aluminum, lead and other substances that are usually solid upon the earth. The sun is very large. Its diameter is more than 100 times greater than that of the earth. It contains a great many atoms. If the silver just of the solar atmosphere could be extracted and brought to earth, rare as that element is, it would form a ball

more than a quarter of a mile in diameter. It would weigh almost a billion tons and its value would be inconceivable.

But the sun is something more than just a conglomeration of atoms—a mixture of chemical elements. It is a machine in the broadest sense of the word—a cleverly designed dynamo that furnishes light and heat to the universe as a whole. True, it is not man-made. It is not a combination of wheels, levers and wires. Nevertheless, somewhere far below the solar surface, there is some sort of mechanism for manufacturing energy. We do not know of just what it consists, but we know it must be extremely powerful. The rating of the solar engine is five hundred sextillion horsepower (500,000,000,000,000,000,000,000) or 80,000 horsepower for every square yard of the solar surface. Only one part in 2,000 millions of the total radiated energy actually strikes the earth, but even if the fraction falling per day upon an area one mile square could be converted into electricity at the rate of one cent per kilowatt hour, its value would be more than two hundred thousand dollars.

These geyser eruptions, the stormy areas we call sun-spots and the form of the sun's corona halo appear to be related in some mysterious manner. They all vary, with a period of about eleven years. We can not tell whether this variability constitutes a menace or not. The earth can not help but be affected to some extent by these conditions. We know that the aurora borealis flares more brilliantly when large sun-spots are present. Simultaneously magnetic disturbances cause interference on the transatlantic telegraph. The rainfall of past centuries, as recorded in the growth of tree-rings, appears to reflect the eleven-year sun-spot cycle. Sun-spots may be called upon at any time to explain a New-England blizzard, a southern drought or "unusual" weather in any section of the country. It has been proved that financial cycles have a period of about eleven years and sun-spots, accordingly, have been blamed for the depression. If there is some indirect connection I am unable to discover it. I wonder why no one has thought of suggesting the converse—that the depression may have been responsible for sun-spots. Many of us had spots before our eyes in 1929.

The reliability and permanency of the sun are remarkable. Frozen in the rocks is a continuous record of life upon the terrestrial surface—from the age of delicate protozoa and animalculae through the period when the earth was dominated by dinosaurs and other Mesozoic reptiles, and on to the modern era and civilized man. Throughout this enormous epoch—five hundred million years or so in length—there is no evidence of the sun's having been shut down for repairs. During this time the intensity of solar heat has never increased to twice or fallen to half of its present value. Otherwise the continuity of the geological record would have been broken. This means that *each* gram (each thimbleful, let us say) of the sun has, within the lifetime of the earth, accounted for more than 1,000 million calories, enough heat to boil ten tons of water. Obviously, this is far greater than could be produced by any *burning* process, such as the complete combustion of an equal mass of pure carbon and oxygen or, for that matter, by any other chemical process. It would be like trying to heat enough water for a dozen baths with the aid of a single match. The magnitude of the energy source is one that may well arrest the attention and the imagination of the engineer. If he could only discover this method of energy production and harness it for mankind, all questions of power supply would be solved for future generations.

Many of us will consider ourselves lucky if our 1929 cars will last only till

the end of the depression. An automobile that has been in service for thirty years is awarded high honors and put in a museum, while the sun's marvelous record of billions of years of continuous service goes unnoticed. This is hardly just. Not that I should recommend putting the sun in a museum—at least not just yet. The Harvard Observatory, feeling strongly in the matter, has placed a symbolic solar motif over the door of the building containing its largest telescope.

Despite such apparent dependability we can not assume that the sun will keep on shining forever. The old maxim that we never get something for nothing is especially true in science. "Free air" for your tires costs the garage owner for equipment and electricity. And "free sunshine" costs the sun a part of its store of energy. Vast as this store is, it can not be inexhaustible. How long the sun can continue shining at its present rate depends upon the type of energy supply—and of this we know practically nothing. Many theories of the origin of the sun's heat have passed in review and have been discarded as inadequate. The combustion theory, as I previously mentioned, is of this type, since it could provide energy for only a few thousand years. Likewise the hypothesis that the heating is due to impacts of meteors has been thrown into the rubbish heap along with the contraction and compression theories.

We appear to be driven to the conclusion that the sun keeps itself going by a process of self-cannibalism. The sun is actually eating itself up, turning its matter into energy, which is radiated away into space and irretrievably lost. By this hypothesis we may fix an upper limit beyond which the sun can not exist—for the sun can not do more than consume itself entirely. If the sun continues to radiate as at present, we find that within ten million years or so, it will have burned itself out completely. Perhaps by a more prodigal expenditure of energy in its old age, the sun might be able to survive longer, but its warming effect on the earth could not be reduced much below its present value if life is to survive. And, of course, the sun may not find itself entirely edible. If only a small fraction of its mass is convertible into energy then the estimate must be proportionally reduced. I should be very much surprised, however, to find the sun fading appreciably before the elapse of many billions of years. You will have to wait with me, I fear, to see whether this prediction is verified. The date is sufficiently far in the future that I doubt whether many of you will worry about the possibility of my having to drop a couple of ciphers from my estimate. A billion years appear to be a short time in the cosmic scheme of things, long as they may seem to you, who, if you chance to be thirty-one years old, have lived about a billion seconds.

The processes I have been describing so far picture the sun as living a normal sort of life and eventually dying of old age, and a ripe old age at that. I can not guarantee, however, that a catastrophe may not intervene to take the sun off in its prime. The chances of hitting another star are practically negligible. The celestial accident insurance rate must be fairly low, much lower than the rate for sickness insurance. Stars may collapse or explode, and we can not be certain that our sun is immune. As a matter of fact the sun's face is pretty well spotted at times; it has skin eruptions—or perhaps they may be more than skin deep; its temperature fluctuates up and down by a few degrees. Yes, we might say that the sun has a mild case of periodic fever. When its temperature is up we have more spots and more eruptions. About eleven years elapse between the times of highest fever and maximum spottedness.

Unfortunately we can not tell how wide-spread this particular type of stel-

lar disease is. All the other stars are too far away for us to get a good look at their faces. We have some reason to believe, however, that many stars are similarly affected and we need not fear that the sun's demise is imminent. Some stars appear to be afflicted with a sort of pulmonary trouble, for they alternately inflate and deflate themselves, like a rubber balloon being blown up by a child who insists on sucking in on every breath. Such a star would not make a very good sun, for its rate of radiation is not constant. We should boil one day and freeze the next. We have little fear of our sun's falling heir to stellar asthma of this kind, since most of the stars that exhibit these symptoms are very much bigger and brighter, as well as more bloated than our sun. There are some stars, like R Coronae Borealis, that go along for years apparently normal and then suddenly decide to take a rest and hibernate. They fade away to a thousandth or so of their usual brilliance, and after a few months' or a year's vacation get back on the job. These stars appear to have lots more carbon in their atmospheres than does our sun, and it has been suggested that their peculiar behavior may be a type of carbon poisoning. If so, our sun is immune, but of this we can not be sure. The ice ages of the past *may* have been due to a temperature lapse of this sort.

Most of you remember reading in the papers last December of the discovery of a new star or nova in the constellation of Hercules. This was not really a new star, but an old one, possibly not unlike our sun, that suddenly burst and attained more than 100,000 times its original brilliance. If such a catastrophe were to happen to our sun, the earth would melt and vaporize; the surface of the planet Pluto, despite its distance, would become little short of red-hot. There are certain features connected with the skin eruptions—those flame-like geysers spurting as I mentioned before thousands of miles out into space—that suggest incipient nova activity. I prefer to think of them as safety valves, the method that the sun uses to blow off steam and thus escape the fate of becoming a nova. If this is right, as long as the fiery geysers continue to spout, we have nothing to fear. But if the sun were suddenly to become and remain quiescent, I should begin to worry—not immediately, but after a few thousand years.

I started out to try to answer the question, "Why take the sun for granted?" I fear that my answers are indefinite and perhaps evasive. We see that we can not absolutely rely on the sun. There is a chance, though a small one, that it will explode within our own lifetimes. So confident am I, however, that the sun will continue to shine with sufficient stability to support life for at least a billlion years that I am willing to wager on it—and give any reasonable odds—say one cent to ten thousand dollars. If you want me to increase the time to ten billion years, the odds will have to be lower. The only condition to the wager is that I be allowed to hold the stakes.

MENTAL HEALTH, HAPPINESS AND EFFICIENCY

By Dr. C. A. BONNER
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MENTAL health might be defined as our mental condition at any given time. There are many degrees of mental health, ranging from the normal, well-balanced attitude to that of worry, anxiety and fear. When we speak of this

last condition, or conditions, we infer that the mental health is more or less impaired, not to the extent of insanity, but to the extent that the individual is handicapped by his innermost feelings and in his effort to be productive at whatever work occupies his time. It is futile or useless for the physician to say to a person in this state, "Do not worry. Everything will be all right." This is scant help in the relief of mental misery and suffering. The problem has deeper significance. The condition arises from within the mind and must be corrected from within the mind. It is not the outward symptoms that should command our attention, but rather the underlying causes producing these symptoms, and only when one has determined by careful analysis what motivates these symptoms can they be helped, and then only by the skilful application of special treatment.

In studying these individuals we find many who are of a particularly sensitive make-up, and there may exist feelings of inferiority without proper reason. They have allowed undesirable habits of thought to dominate their minds. In these cases it is necessary for the individuals to make an inventory of their lives and to evaluate properly their achievements, as so often they only see their failures. We should develop a philosophy of life which will enable us to have a proper perception of our achievements and to learn not to be overwhelmed by disappointments that are an inevitable part of life. There is a second group, particularly in this period of depression, where the anxiety is directly dependent upon economic, social and other troublesome situations over which we have no control. These are due to external circumstances and, of necessity, the correction will have to be of a material nature.

The description thus far relates to the development of the so-called nervous breakdown, and this condition, if allowed to persist, may become a serious mental disorder. The problem of mental diseases is one which touches nearly every person directly or indirectly. If we are so fortunate as not to have a loved one in a mental hospital, at best we are sharing the burden of caring for the insane. Records would indicate that of all hospital beds 50 per cent. are devoted to the care of the mentally ill. The community has met the situation by improving hospitals for the care of the insane. Briefly, we might contrast the custodial institutions of fifty years ago with the bright, sanitary, progressive state hospitals of to-day, where a patient is received with the determination to provide effective treatment, to plan for improvement and cure and for helpful supervision after the patient has left the institution.

Since the problem is so close to all of us we should be keenly interested in methods of prevention. The prevention of mental disease is just as important as the prevention of physical disease, and our greatest hope lies in developing methods through popular education in the field of mental hygiene. We believe that childhood is the golden age for mental hygiene. It is during the early years when the child is plastic that good habits of thought and behavior can be incorporated. Child guidance clinics have now been established in nearly all large cities to aid parents in dealing with the problems of their children. Professional advice for the nervous or problem child will pay big dividends later in life and properly prepare him to meet the difficulties of adolescence. It is in adolescence that the larger proportion of mental diseases develop. Boys and girls of high-school age, who show tendencies to be seclusive, unfriendly and with a pronounced lack of interest in their usual mode of living should be given careful attention, as these are often the early signs of a beginning mental illness. If the com-

munity were educated in the detection of early symptoms we might spare many parents the grief of learning that this dreaded illness has become thoroughly ingrained and little improvement can be expected. After the period of adolescence the responsibility for our mental health rests with us alone. Maturity does not necessarily make us immune from mental illness, and we must observe continued thought and care toward the preservation of mental health.

Particularly, later on in life when there is a decline involving the mental and physical powers of the individual must one exercise vigilance and often effect adjustments. There is a tendency at this time to look back on life, to emphasize mistakes, to minimize successes and to look ahead to the future only with dread. This mental attitude is intensified when these people find themselves beset with physical infirmities and with the realization that they have lost their active memories and powers of concentration. Mental hygiene has two good suggestions here. First, fixation on the physical symptoms must be avoided, lest from a few real symptoms there develop a multitude of much more incapacitating ones. Second, the mental activity of these persons must be continued as usual. By keeping young in interests and in mind and by directing attention toward the use of their mental functions they will be stimulated through their own activity to feel that life still holds much in store.

The goal of the human mind is to direct the body. An unhealthy, poorly balanced mind will not lead to achievement, happiness or efficiency. Only those who can view life's ups and downs with equanimity, maintaining a calm and clear outlook on life, can reach happiness. It is generally agreed that it is the person with a happy mind who is most productive. How can we produce our best when we allow ourselves to be ruffled by intensities of feeling all out of proportion to the causes? True happiness comes from within ourselves, from our own mental attitude, rather than from external conditions.

It is well known that unwarranted worry is one of the most dangerous agents in upsetting mental equilibrium. This fact can not be stressed enough because Americans as a people are prone to worry. It is worrying over one's work that is usually the cause of mental upsets and nervous breakdowns rather than the actual physical effort exerted. Worry is destructive to happiness and invariably impairs efficiency.

Edward Everett Hale has expressed in these words excellent advice along these lines. "We should never attempt to bear more than one kind of trouble at once. Some people bear three kinds—all they have had, all they have now and all they expect to have. Within that statement is set forth the essence of mental hygiene. If we could only keep these words before us constantly our days would be more serene, our nights more restful, and our production would reach its fullest extent with happiness and efficiency.

DEMONSTRATION OF DIFFERENCES BETWEEN PEOPLE IN THE SENSE OF SMELL

By Dr. ALBERT F. BLAKESLEE

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"ARE Freesias fragrant? Some say 'yes'; many say 'no,'" was the main label on an exhibit at the International Flower Show which was held this last March in New York City's Grand Central Palace. On a table between two vases of flowers a placard was more specific in its questions and read: "Can you smell these flowers? If so, is the odor weak, medium or strong and do you like it?" Other placards requested visitors to register their reactions to the flowers on the voting machine with the help of the attendant. It was stated that the records would assist in a study of the sense of smell and be of value to science.

The response to the labels was greater than had been anticipated. Although the exhibit was on the third floor, which was less crowded than the floors lower down, a total of over 8,400 registered their votes regarding the odor of two flowers, or a total of over 16,800 votes on floral odors. During the rush hours people were often two and three deep in front of the table which held the flowers, and many left before reporting their vote to the attendant at the voting machine or even before trying the flowers, which were inaccessible because of people ahead of them. The original plan had been to allow each person who smelled of the flowers to register his reaction on the voting machine without aid, as had been the method employed in similar demonstration tests of taste.[1] To this end appropriate labels were pasted over the levers on the machine. The first classification was in regard to strength of the odor. "If there is no odor," "If the odor is weak," "If the odor is medium" and "If the odor is strong," each of these captions had underneath it the direction "vote below." Arrows pointed to the subdivisions, indicating the attractiveness of the odor to those who could smell it. Thus the ultimate lever pulled down would be one of the following: "no odor," "weak and pleasant," "weak and indifferent," "weak and unpleasant"; "medium and pleasant," "medium and indifferent," "medium and unpleasant" or one of the three subdivisions under strong. With the numbers involved, individual voting was soon found to be impractical. The system ultimately adopted was to have at least two attendants always on duty throughout the exhibit.[2] The writer was present during at least part of each of the six days that the flower show was open and took his turn in acting as attendant. The two flowers exhibited each day had contrasting colors, and the "A" flower, which was furthest from the machine, was chosen as having a relatively weak odor to most people, while the "B" flower was selected as being relatively strong. One attendant stood by the "A" flower and explained the purpose of the test and also prepared the visitors for the replies to be given to the atten-

[1] A. F. Blakeslee and A. L. Fox, *Jour. Hered.*, 23: 97–107, 1932; A. F. Blakeslee, *Science*, 81: 504–507, 1935.

[2] The following, at one time or another connected directly or indirectly with the Department of Genetics, took part as attendants: Mr. and Mrs. A. G. Avery, Mrs. A. F. Blakeslee, Mrs. H. R. Brindle, Mrs. E. P. Burtch, Dr. J. L. Cartledge, Miss Helen Houghtaling, Mr. M. J. Murray, Miss Miriam North, Miss Sophia Satina, Miss Lilias Shepherd, Miss Jennie Schultz.

dant at the voting machine. Each was asked to smell of the "A" flower first and say if it had any odor. If an odor was perceived it was to be described as to its strength as weak, medium or strong and also as to its attractiveness as pleasant, indifferent or unpleasant. The visitor was asked then to smell the "B" flower and report his reactions regarding both flowers to the attendant who manipulated the voting machine. Some confusion and loss of votes necessarily resulted from visitors coming from both sides, but the best that could be done without controlled traffic was to make frequent announcements that the "A" flower was to be smelled first. When the system worked well the attendant at the machine could register votes on the pair of flowers at a rate of between two and three a minute.

As a demonstration of the differences between people in their olfactory reactions, the exhibit appeared to be a success, if one can judge from the frequent expressions of surprise when a companion reported what seemed to be an impossible reaction. The "A" flower might be strong to one and weak to another or even without odor, but when the two came to the "B" flower their reactions might be completely reversed. In attractiveness of the odor there was no less divergence of opinion. What was described by one as a delicious perfume might be characterized by the next as an intolerable stench. All the possible combinations of reactions were registered for each kind of flower by at least a few persons with the exception that no votes were recorded "strong and indifferent" for the Apotheose Freesia. The machine was not adjusted so that it could be possible to tell from the records how the same person reacted to both the "A" and the "B" flowers. It was observed not infrequently, however, that a person would call the "A" flower strong and the "B" flower weak or even entirely without odor, although in so doing he was registering reactions opposed to the majority of smellers.

Our selection for each day's test of a pair of flowers with contrasting weak and strong odors was based on previous tests with a sufficient number of persons to make reasonably sure that the majority would find the "A" flower weak and the "B" flower relatively strong.

The summary of the reactions as recorded on the voting machine will be discussed in more detail later. It may not be amiss to give first some of the more general impressions noted by those of us who acted as attendants. The exhibit had much in the way of interest to a student of human reactions in ways that could not be recorded on the machine. Some of this material related to differences in the sense of smell, but much involved differences in general behavior or attitudes of mind.

It was anticipated that there might be some who would make false reports in the way of a prank on the investigation, but their number must have been too small to have had any material effect upon the records.

All the attendants were impressed with the evident interest and sincerity of those taking the tests. Most subjects appeared to make a serious attempt to report accurately the reactions experienced, although some had difficulty in self-analysis. There was not an unnatural tendency to grade the strength of one kind of flower in terms of the other, and the remark would often be made that the "B" flower was stronger than the "A." In such cases the request was made to state the strength of odor of each kind of flower as if it had been smelled by itself and to make the comparison with one's general idea of what would be called a weak, medium or strong odor. If the subject seemed to be in doubt whether to call a flower pleasant, indifferent or unpleasant, he was asked if he liked the odor, disliked it or just didn't care. He was encouraged to

classify the odor as indifferent if pleasant and unpleasant elements were found in the odor which seemed to about equally balance, as was often the case.

It was of considerable interest to note how much people differed in ways aside from their reactions to the odors of the flowers. The idea of testing their senses seemed to appeal to most visitors and they voted with evident pleasure without need of urging. Many brought their friends after voting themselves and a considerable number took the tests again on later days when new varieties were exhibited. Some, however, seemed disinclined to take part, perhaps from fear of showing their inability to detect the odors if they announced their reactions. We had the impression that proportionately more men than women were thus timid at the thought of taking the test. A considerable number of the men who actually voted did so at the invitation of their wives. It was of amusement to the onlookers when members of a family failed to agree on the odors. That they were doing something that would aid science was a satisfaction to some, and a mother was overheard insisting that a reluctant daughter report her reactions to the attendant because it would help science and science ought to be encouraged. A young lady of modern appearance, however, was heard to say that she didn't want to help science, science had never helped her. She had evidently been helped, but perhaps it was art rather than science that had had the most influence.

Some few were opposed to the tests on general principles. They said they were unfair for various reasons and just wouldn't show anything anyway. One woman, for example, before trying the flowers insisted that the whole affair was foolish. "Everybody knows that Freesias have a lovely odor and to ask if Freesias are fragrant is a silly question." It was suggested that she try the two varieties on the table herself and notice for a while how others voted. She started with the "A" flower and turned on us indignantly, "There is something the matter with these flowers, they don't smell at all! You have done something to them." She was assured that they had not been doctored in any way. As she put her nose down among the "B" flowers, her features relaxed and with a smile she exclaimed "A perfectly heavenly odor." While she waited watching the others, a man approached the "A" flowers which she had been unable to smell and called them strong. Upon smelling the "B" flowers (Leucocoryne) which the woman had called heavenly, the man's features hardened and he turned to the attendant almost with anger and said, "Lady, these stink, they stink like h—." The objecting woman's face flushed and she left the group without further objections. Similar situations occurred from time to time in which some one made the unexpected discovery that people really are different in their smell reactions, but none was more dramatic than the one described.

A number of psychologists, amateurs as well as professionals, pointed out factors which would prevent the tests giving reliable results. In all such cases we were able to enumerate more factors than they had mentioned which would render the results difficult of interpretation. We explained that the tests were to be considered more in the nature of a rough survey than as an adequately controlled experiment. The exhibit was modestly labeled merely a demonstration and appeared to be living up to its label. We, as well as the visitors, were learning things we had not known before and we hoped the records might turn out to have some scientific value as a by-product.

To some there was doubt as to the object of the tests and a few, mostly among the men, were even suspicious of some kind of a "racket." A very common question was, "What are you try-

ing to prove?" The answer generally given was that we were not trying to *prove* anything, but rather trying to *find out*, which was the attitude of scientific experiment. This reply was not entirely satisfactory, and one man voiced his doubts by saying, "What is the joker in this game anyway?" Several women thought the exhibit was an advertisement scheme to sell flowers and wanted to buy some. One man, after having his vote registered, held out his hand and said, "Don't I get my fortune, or something?"

Regarding their attitudes toward their own sensations, there appeared to be two main classes of people. There were those who made their own decisions as to how the odor should be described and could not understand how anybody could think otherwise. There were also those who considered the tests in the nature of an examination in which they tried to give the correct answers; they appeared to seek an authority outside of themselves. Of those who looked to themselves for sole authority there were many examples. If others found an odor where no odor could be detected by a person in this class the others were often believed to be laboring under a hallucination. A negative reactor to both the "A" and "B" flowers shifted the blame from his own shoulders with the following words: "You can't smell these flowers so long after they are cut; but the trouble is the public don't know it. They just fool themselves." One woman who could not smell either of the two Freesias exhibited said that the Freesias had lost their fragrance through hybridization. She had a very keen sense of smell, she said; in driving through Connecticut she could smell tobacco from the growing plants long before the fields were in sight and could detect sewer gas when no one else could, not even the plumbers who were looking for the leak. Therefore, she said, the other people at the show just imagined they could smell the flowers and were actually telling us lies, because in reality the Freesias did not have any odor.

A frequent and somewhat more generous explanation was the influence of some factor such as a cold in the head which had rendered the patient's olfactory organs temporarily less acute than normally. Other people who failed to detect odors that appeared perfectly obvious to most were said also to have something the matter with them or to be abnormal. This inability of others was often attributed to their use of tobacco. "Too many cigarettes are why so many men can't smell the flowers and the women are getting just as bad now," was a typical explanation.

Some who failed to detect an odor said that those who smelled it got their odor, not from the flowers on our table, but from the general Freesia odor in the air. Others claimed that the Freesia odor in the room prevented them from smelling the individual bunch in the exhibit. This may have been true in some cases, since banks of Freesias were on exhibition not far from our table. Many experienced the phenomenon of smell fatigue, since they detected the odor at first but lost it upon prolonged smelling. Those taking the tests were asked, therefore, to get their reactions from a few sniffs only.

The possibility of olfactory fatigue led us to put the two vases of flowers at some distance apart on the table and to request the visitors to smell of the "A" or weak flower first. Before this was done, some thought it made a difference in detecting an odor which flower they smelled of first. Perhaps also connected with fatigue was the fact that several persons said they could smell the odor a little way off but not near to. Some called this odor away from the flower the "echo" odor.

Some thought our Freesias must be dead because "they always smelled Freesias," but couldn't smell these.

Some who got weak or no odor thought the flowers were "smelled out," *i.e.*, that repeated smelling destroyed or used up the fragrance.

Environmental factors do have a marked influence upon the sense of smell, much more so apparently than upon the sense of taste, and some of the numerous explanations proffered by certain persons for their poor showing in the tests may be reasonable. It seemed strange, however, how seldom visitors appeared to realize that the difference observed in their reactions to odors was probably, in part at least, attributable to innate differences in individual constitution. This is clearly the case with the sense of taste. Others, as well as the writer, have shown that differences in taste acuity are inherited.

Of those who were not quite sure of the correctness of their reactions and appeared to want an authority outside of themselves to say if they were right, there were numerous examples. Many upon hearing the purpose of the test explained would say, "After I smell will you tell me the right answer?" "Was that the right answer?" or some similar question was the most frequent remark addressed to the one who manipulated the voting machine. To one young lady who asked the common question "Did I vote right?" the writer replied, "Yes, you voted exactly right." Smiles came to the face of the questioner, she had achieved success. The next person voted the exact opposite, and she also was assured she had voted right. A look of surprise came over the face of the first questioner. "But, Professor, she voted different. We both can't be right." Each one was right, she was told, because each one alone could tell what her own reactions are. "But, Professor, how do they smell to you?" To her mind apparently the professor knew the answer but was holding it back from her, as professors have a way of doing for some unknown pedagogical reason.

Some of the seekers for authority looked for it not in single individuals, but from their training in a democracy seemed to think that the majority must be right. Instead of appealing to the attendant with the question, "How should they smell?" they would want to know how the majority voted, apparently with the desire of being on the winning side.

The desire to relate their own reactions to those of the majority was responsible no doubt for part of the interest in the records of previous days' voting which was posted near the exhibit. Many, however, appeared interested in the tests as an experiment entirely aside from their own part in it, and the question was frequently asked as to when and where the results would be published.

One's reactions to odors are much more influenced by associations of one kind or another than is generally realized. Associations may be responsible for one's finding an odor pleasant which is highly objectionable to most people as well as finding another odor unpleasant which most think of as a pleasing fragrance. A man who was asked whether the odor was pleasant or unpleasant replied: "Oh, I sell perfumes. They're all the same to me." The writer finds he has a similar reaction in that he is unable to call any odor unpleasant with which he is experimenting. His interest is in the experiment, and the odor is a part of a pleasurable experience.

Associations appeared to have an influence also upon one's estimate of the strength of odor. The beauty of the flowers made a strong appeal, especially to the women, and may have raised a presumption in their favor when the question was raised whether their odor was pleasant or unpleasant. It was sometimes difficult to get people to consider the odor apart from the appearance of the flowers. "No, I don't like the

pink ones; never have liked that color," was the remark of one young woman. "But the odor, do you like it?" she was asked. "No, I don't like pink," and she left without giving us an opportunity to record her olfactory reactions to the Freesias which had the misfortune to be born pink. Preconceived ideas as to what ought to be may have had influence at times on the reactions reported. Frequently visitors did not want to admit that they could not smell the odor of the flowers but would often do so when they were told that on the first day over half the people could not smell one of the flowers on exhibit. How others voted had some influence apparently on succeeding votes. Often the second of a pair would say, "My vote is just the same as what the first one gave." When we replied that we had to record the votes for each one separately and had no place to vote ditto, the reaction finally reported would generally not be a repetition of the first. Many upon reading the sign "Are Freesias fragrant?" would exclaim "Why, of course they are," even before trying to smell them. Some would approach the flowers with the remark, "Oh, yes, colored flowers are always fragrant." Others would say just the opposite. Most who commented on the relation between color and odor claimed that the white flowers are far superior in odor, although a few said that white ones are weaker. Color of the flowers or the varietal names may have had some influence upon the description of their odor which many volunteered. The orange-colored Freesia, which carried the varietal name of Tangerine, perhaps would not have had its odor described so frequently as like oranges and tangerines if it had had a white flower and been called by a less suggestive name.

It was probably due to association rather than to an exceptionally acute sense of smell that a woman reported to an attendant that she was capable of long distance smelling. She was absolutely sure she could smell over the telephone. There was a man who was a great friend of hers, who often smoked a very strong pipe and several times when she called him on the phone as soon as he said "hello" she could get this very strong tobacco odor. "You just see if this isn't something I have discovered as you go on with your investigating." This was not the only instance of the kind. Another woman in passing the exhibit was overheard to tell her companion that she could smell over the telephone.

Visitors were found to be willing not only to answer the simple questions put to them for purposes of record, but also volunteered information not asked for. It was especially the women who desired to describe the odor of the flowers in terms of something else. The difficulty that any one person has in classifying odors is well known. The difficulties are not lessened when many people attempt to describe an odor. Although individually many people seemed able on different days to distinguish the "A" from the "B" Freesias by quality as well as by strength of odor, it would be impossible from any single description to know which Freesia was being referred to.

It may be of interest to give from our notes some of the characterizations of the odor of the "Tangerine" Freesia exhibited the last two days of the show. Among the descriptive terms heard a number of times are the following: peppery, pungent, spicy, bitter, woodsy, grasslike and medicinal. The odor was frequently compared with that of oranges, tangerines or citrus fruits in general, dandelions, orange blossoms, honey, hay and soap. The odor was also said to resemble that of lavender, buttercups, verbenas, marsh marigolds, wood violets, saffron, crocus, goldenrod, orange marmalade, tea, sandalwood, peppermint, Japanese lacquer, paprika, aromatic spirits of ammonia and skunk

cabbage (but pleasant). Perhaps equivalent to the adjective "woodsie" is the description of the odor as fresh, like spring, or cool, like wet sawdust. One visitor found a strong association with his youth and said, "It smells like a straw bed I slept in when a boy—the kind they used to have in Missouri."

To some the odor was of a character that could hardly be classed with ordinary floral odors. The following remarks were overheard: "It has no odor, but gives a sensation of intoxication." "You can't smell it; you just feel it." "No odor, just an out-doors smell."

The "B" flower on the last two days was not a Freesia but an equally attractive flower called the "Glory of the Sun" (Leucocoryne ixioides). To the writer it had a compound odor with two distinct elements. One resembled the fragrance of heliotrope and was pleasant, the other resembled the odor of fleshy fungi and was of a type that would be called unpleasant by most people. The writer's associations established by working with fungi prevented his finding this element in the odor unpleasant. To those who liked the odor of the Leucocoryne, it smelled most frequently like heliotrope, though it was also compared to the odor of hyacinth, narcissus and mignonette. The other element was probably uppermost in the minds of those who described the odor in the following terms: queer swampy odor, musty, like decaying mushrooms, like yeast, purple trillium, sour, like blue sour sapwood, carbolic acid, a sanitarium, bitter almonds, skunk cabbage, anise and licorice cake. Some used in their descriptions some of the same terms applied to the Tangerine Freesia, such as like dandelion, honey and woods in spring time. Some detected only one of the two odors which were distinct to the writer, but others could distinguish both. These latter often reacted differently to the two components, some finding the first, others the second the stronger. Many found a pleasant and unpleasant component about equally distinct and had difficulty in deciding whether to call the odor of the flower as a whole pleasant or unpleasant.

Visitors often were not content to discuss merely the odors of the flowers exhibited, but in addition related interesting experiences they had had with other odors. These conversations, however, were by no means confined to the sense of smell, and at times the writer felt in a way as if he were officiating at a confessional, since he was told much that is not generally related. All that was told emphasized, often in unsuspected ways, the great diversity between people in their sensory reactions. There are not a negligible number, for example, who can recognize other people by odor in the same way in which dogs can distinguish different individuals by scent alone. This power is more frequent in children, but is often retained into adult life. There is a social taboo against speaking of personal odors, and this extreme acuity of smell is generally concealed by its possessor.

At the opposite extreme were the surprisingly large number of people who reported that they had lost the sense of smell. To some the loss had come gradually, to others rather suddenly. Some could connect it with nasal disease, such as a cold or sinus trouble or to an operation; others could offer no explanation. Most were questioned regarding whether after the loss of smell they could still detect flavors which are generally classified as odors. The majority thought they had not entirely lost the perception of flavors. Since it is difficult for a person clearly to separate all the sensations experienced in the mouth it is possible that in such cases only the primary tastes for bitter, sour, sweet and salty had been retained. The question has considerable interest in interpreting sensations perceived by way of mouth and nose, respectively, but can be settled only

by tests of individual cases. Some of the instances of loss of smell (called anosmia) had family histories which suggested that hereditary factors were involved. One woman had lost her smell when she was about 25 years old. She had one anosmic brother who lost his smell when he was between 30 and 40, in addition to six normal brothers and one normal sister. Her mother was anosmic and was highly sensitive to flax seed and her maternal grandfather suffered from hay fever.

Those just discussed had apparently lost their sense of smell permanently, but others reported that the loss which had come from a cold, an operation or from unknown causes had been of shorter or longer duration but that the ability to smell had ultimately returned. There was one person who said he had never been able to detect odors, and cases of total anosmia from birth are reported in the literature.

From the foregoing discussions it is evident that people differ in ways that could not be recorded on our voting machine. Even though the records give an idea of the range of variation in acuteness of smell they were in many respects difficult to interpret, since the environmental conditions of the tests could not be controlled. The odor of the flowers probably varied, becoming fainter during the day, as was indicated by the votes recorded hourly which showed an increasing number of people who voted no odor toward the end of the day. Individual differences were noticed between different flowers in the cluster. It is not unlikely that differences in such factors as temperature, relative humidity and barometric pressure of the air on different days may have had an influence upon the production of odors in the flowers or upon the smelling abilities of the visitors. The mixture of floral odors in the building no doubt conflicted with the tests, but more disturbing were the synthetic chemicals sprayed upon visitors who ventured too near a booth labelled "Perfumery" which was located on the same floor. All these environmental factors tended in a measure to average out so that the records on a given day are probably fairly comparable. There were other factors, however, associated with the personalities of the different attendants. The way one voted was influenced by the way in which the test was explained and the questions asked. With a little encouragement, such as a statement of the relatively large number who could detect no odor on an earlier day, the number who voted "no odor" could be increased.

Despite all the influences that we feared would detract from the reliability of the tests, the summary of the votes shown in Table 1 contains evidence that the tests give a fair measure of the relative strengths of different floral odors and of the relative abilities of people to detect these odors. All the flowers in the table, except the white No. 5, had been used in a lecture demonstration a year previous and the strength and attractiveness of their odors at that time were in the same relative order as at the flower show. An indication that the method can detect differences in strength of odor in the same varieties may be seen from the records of the Freesia varieties Maryon and Golden Daffodil on Monday in comparison with those of the same varieties on Tuesday and Thursday. On Monday the odor for both was decidedly weaker as shown especially by the relative number who voted "no odor." This great difference between other days puzzled us until we learned that the flowers on Monday had been kept 24 hours longer after picking than on other days. The grower's schedule for week days involved cutting the flowers at about 11 A.M. and keeping them in a cool head house till about 5 P.M., when they were packed in boxes ready for trucks which picked them up between midnight and 2 A.M. and deliv-

ered them to the wholesale dealers between 3 and 5 A.M. They stayed in the boxes till the wholesaler took them out about 7 in the morning. An attendant brought them to the flower show between 9 and 10 o'clock, when the show opened. The flowers for Monday, however, had been cut on Saturday morning and apparently had lost some of their fragrance by longer standing.

Let us first consider the information in Table 1 from the standpoint of the grower, Mr. C. J. Van Bourgondien, of Babylon, Long Island, who had kindly provided the Freesias used in this and earlier tests. The interest here lies in discovering the relative strength and attractiveness of the odors of the different varieties. No single nose could be used as an adequate standard of how the

TABLE 1

	Flower "A"		Flower "B"	
	Number	Per cent.	Per cent.	Number
	Monday			
	Freesia var. Maryon (Blue) 990 votes.		Freesia var. Golden Daffodil (Yellow) 987 votes.	
No odor	508	51.31	10.44	103
Weak	423	87.76	31.79	281
Medium	49	10.17	43.67	386
Strong	10	2.07	24.55	217
Pleasant	359	74.48	87.90	777
Indifferent	100	20.75	5.88	52
Unpleasant	23	4.77	6.22	55
	Tuesday and Thursday			
	Freesia var. Maryon (Blue) 2,837 votes.		Freesia var. Golden Daffodil (Yellow) 2,831 votes.	
No odor	952	33.56	5.26	149
Weak	1562	82.86	19.57	525
Medium	270	14.32	39.78	1067
Strong	53	2.81	40.64	1090
Pleasant	1466	77.77	85.94	2305
Indifferent	311	16.50	6.97	187
Unpleasant	108	5.73	7.08	190
	Wednesday			
	Freesia var. Apotheose (Pink) 1,734 votes.		Freesia var. Van Bourgondien No. 5 (White) 1,728 votes.	
No odor	529	30.51	6.94	120
Weak	990	82.16	32.59	524
Medium	180	14.94	43.28	696
Strong	35	2.90	24.13	388
Pleasant	885	73.44	84.82	1364
Indifferent	249	20.66	9.76	157
Unpleasant	71	5.89	5.41	87
	Friday and Saturday			
	Freesia var. Tangerine (Orange) 2,859 votes.		Leucocoryne ixioides "Glory of the Sun" (Blue) 2,864 votes.	
No odor	478	16.72	1.15	33
Weak	1289	54.14	18.72	530
Medium	736	30.91	38.33	1085
Strong	356	14.95	42.95	1216
Pleasant	1431	60.10	59.94	1697
Indifferent	526	22.09	10.84	307
Unpleasant	424	17.81	29.22	827

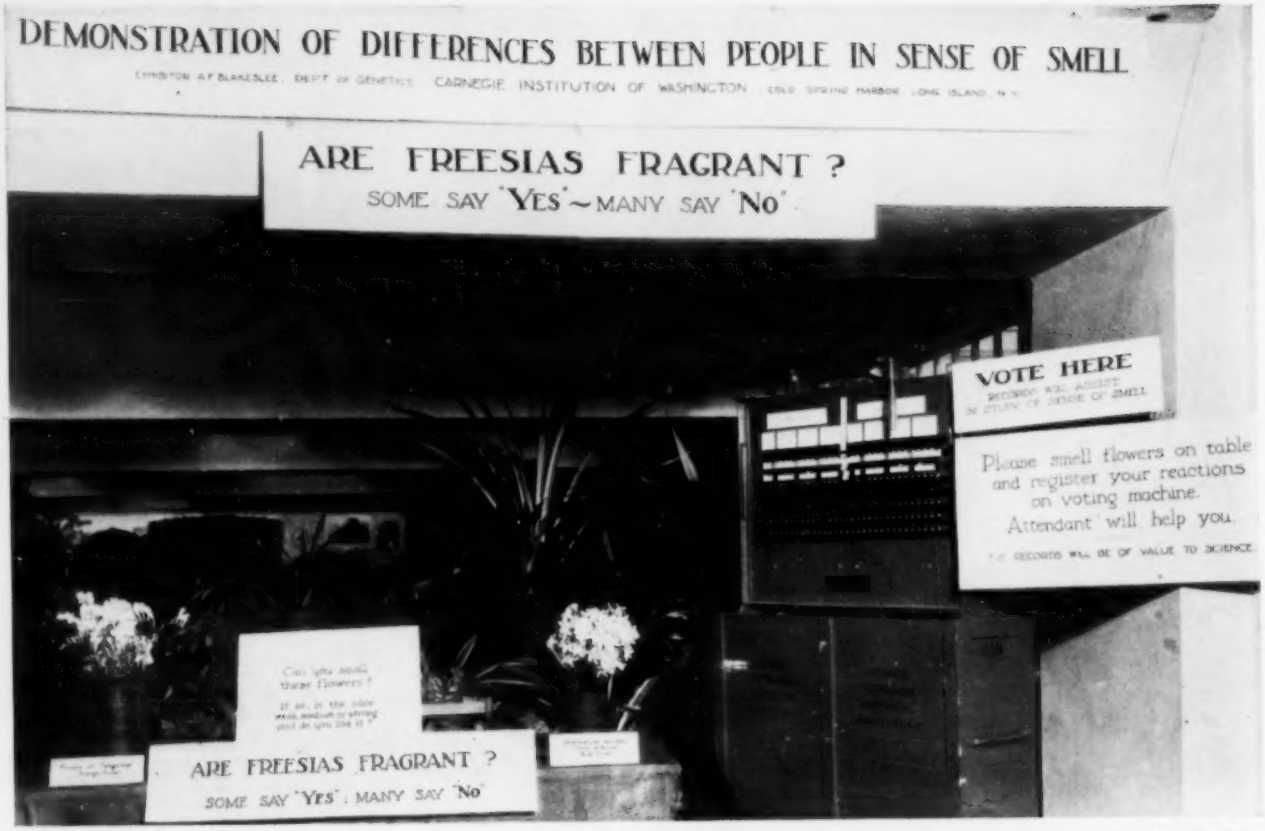
Wide World Photo

A. G. AVERY REGISTERING A VISITOR'S REACTION TO ONE OF THE FREESIAS.

majority react to a given odor. The grower, for example, believed his White No. 5 to have the strongest and best odor of any Freesia and was greatly surprised therefore to see that in the judgment of the public his variety "Golden Daffodil" was stronger. This latter variety received slightly fewer votes for "no odor," had significantly fewer votes for weak (20 per cent. against 33 per cent.) and considerably more for strong (41 per cent. against 24 per cent.). In attractiveness of odor there was probably no significant difference, although a slightly higher percentage called the odor of the Golden Daffodil pleasant. In strength of odor, the Maryon may be listed as the weakest, with Apotheose slightly stronger and slightly less pleasant. Tangerine was intermediate in strength of odor, but the odor was unpleasant to a higher proportion of people than was the case with any other Freesia. Among varieties with strong odors, the Golden Daffodil was strongest with Van Bourgondien's White No. 5 next in strength.

The odor of the Leucocoryne was stronger than that of the Freesias, and to a large proportion of the visitors was distinctly unpleasant. As explained earlier, the odor had two distinct components to which people reacted differently. It should be pointed out that the reactions recorded refer to odors smelled when near the flowers. If the odors had been diluted by distance, the reactions would have been different.

The information in Table 1 furnishes probably the most extensive data so far assembled regarding the judgment of the public as to the odor of flowers. Whether such information is of commercial value can be determined by those in the trade.


DEMONSTRATION OF DIFFERENCES BETWEEN PEOPLE IN SENSE OF SMELL
EXHIBITOR A.F. BLAKESLEE, DEPT. OF GENETICS, CARNEGIE INSTITUTION OF WASHINGTON, COLD SPRING HARBOR, LONG ISLAND, N.Y.
ARE FREESIAS FRAGRANT ?
SOME SAY "YES" ~ MANY SAY "NO"
VOTE HERE
Please smell flowers on table and register your reactions on voting machine.
Attendant will help you.
ARE FREESIAS FRAGRANT ?
SOME SAY "YES", MANY SAY "NO"

Herbert Studios

VIEW OF THE EXHIBIT SHOWING THE TWO VASES OF FLOWERS WHICH VISITORS WERE REQUESTED TO SMELL AND THE VOTING MACHINE ON WHICH THEIR OLFACTORY REACTIONS WERE RECORDED.

SMELL AND THE VOTING MACHINE ON WHICH THEIR OLFACTORY REACTIONS WERE RECORDED.

It has been a matter of surprise, however, to learn how little those whose business it is to cater to the taste and odor preferences of the public take into consideration the fact that people differ in their sensory reactions of taste and smell. After reading papers on differences between people in taste and smell reactions, an official of a firm which deals in products whose sale value is determined by their flavor confessed to the writer that he doubted if the concentration of the flavors was a matter which should be determined solely by the vice-president, as apparently had been their custom.

Whether an odor is pleasant or unpleasant is determined both by the nature of the odor and the associations which have become tied up with it and also by its strength. Odors which are too strong are unpleasant, but what is strong to one may be weak to another person. These conclusions are evident from tests with odors much more concentrated than those given off by the flowers in the exhibit. The data in Table 1 are not arranged in a way to show the relationship between attractiveness and strength of odor. The fact that the Tangerine variety was unpleasant to a larger percentage than the stronger "A" Freesias might seem to indicate that in these tests strength of odor had little if any connection with unpleasantness. A different conclusion is reached for the Tangerine and other varieties when the votes are listed to show what proportion of those who called the odor pleasant found it also weak or strong. In this calculation the uncertain records "medium" and "indifferent" were not considered, and the percentages were based on the extremes, weak and strong, pleasant and unpleasant. For the weak or "A" Freesias, of those who called the odor pleasant, 92 per cent. found it weak and 8 per cent. found it strong; whereas of those who called the odor unpleasant, 68 per cent. found it weak and 32 per cent. found it strong. For the strong or "B" Freesias, of those voting pleasant, 40 per cent. voted weak and 60 per cent. voted strong; whereas of those who voted unpleasant, 36 per cent. voted weak and 64 per cent. voted strong. For the Leucocoryne, of those who voted pleasant, 32 per cent. voted weak and 68 per cent. voted strong; whereas of those who voted unpleasant, 21 per cent. voted weak and 79 per cent. voted strong. In all these cases an increase is noted in the proportion of those who find the odor strong as we change from pleasant to unpleasant.

After the first two days, the votes of men and women were recorded separately. Summaries of these records are shown in Table 2 for all the Freesias, grouped together, and for the Leucocoryne. Significant differences are evident in the way in which men and women voted, but it is doubtful if this fact indicates any differences in the olfactory acuteness of the two sexes. If one considered records on the Freesias only, one might argue that the differences were connected with the evident greater appeal that flowers make to the feminine mind. Women were therefore more inclined than men to call an odor pleasant which was associated with beautiful flowers. They were more hesitant to say there is no odor, and when they reported

TABLE 2

PERCENTAGES IN DIFFERENT CLASSES

	All Freesias		*Leucocoryne*	
	Total voting: men, 2,196	women, 6,761	men, 786	women, 2,078
	Men	Women	Men	Women
No odor	19.44	17.07	2.03	0.80
Weak	56.88	52.54	17.15	19.01
Medium	27.51	29.29	42.06	37.01
Strong	15.61	18.17	40.80	43.99
Pleasant	67.74	75.09	64.98	57.20
Indifferent	21.42	15.41	10.67	11.01
Unpleasant	10.84	9.50	24.35	31.80

an odor they were more inclined to rate it as strong or at least as medium. It also has been suggested to us that since men as a group are less interested in flowers they were more inclined to tell the truth when they found them without odor. The explanations suggested, although in accord with impressions of attendants at the flower show, can not be applied without modification to all odors, since the differences between the sexes in reaction to the odor of Leucocoryne were in most cases the opposite of what they were for Freesias. A component of the odor of Leucocoryne was unusual for a flower. This unexpected and strange odor may have shocked the women more than it did the men, who are relatively indifferent to how a flower looks or smells, and hence fewer women voted pleasant. We can only conclude that there were differences between men and women in the way in which they reported their reactions to the floral odors, but the cause of these differences is unknown.

The exhibit showed, even under the unfavorable conditions prevailing at the Flower Show, that it is possible by the simple method employed to demonstrate in dramatic manner the fact that people differ widely in their sensory reactions to odors. The records are of value in showing something of how wide these differences are. Of considerable value also was the unanticipated information gleaned from personal conversations with visitors, since it helped to orient the writer in a difficult field and pointed to problems that need investigation. The writer wishes to acknowledge his indebtedness to those who contributed to the success of the exhibit: to Arthur Herrington, secretary of the International Flower Show, who provided space for the exhibit; to Russell F. Griffen, who placed a voting machine at our disposal, and A. R. Bailey, who cared for the installation of the machine at the Flower Show; to C. J. Van Bourgondien, of Babylon, Long Island, who provided the flowers for the demonstration; and to those already named who acted as attendants at the exhibit and took notes of the interesting comments made by visitors whom they tested.

THE PROGRESS OF SCIENCE

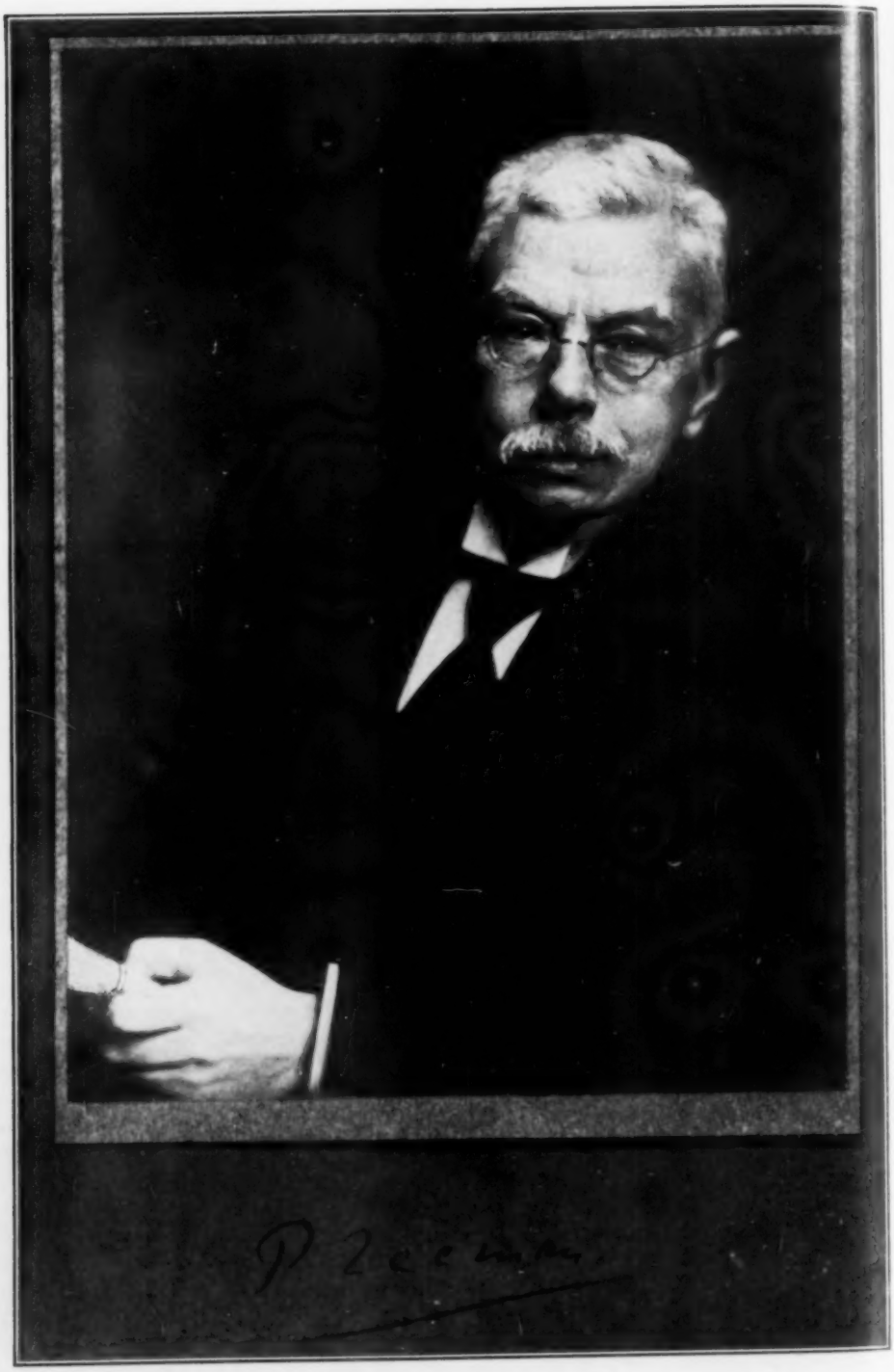
THE SEVENTIETH ANNIVERSARY OF PROFESSOR P. ZEEMAN

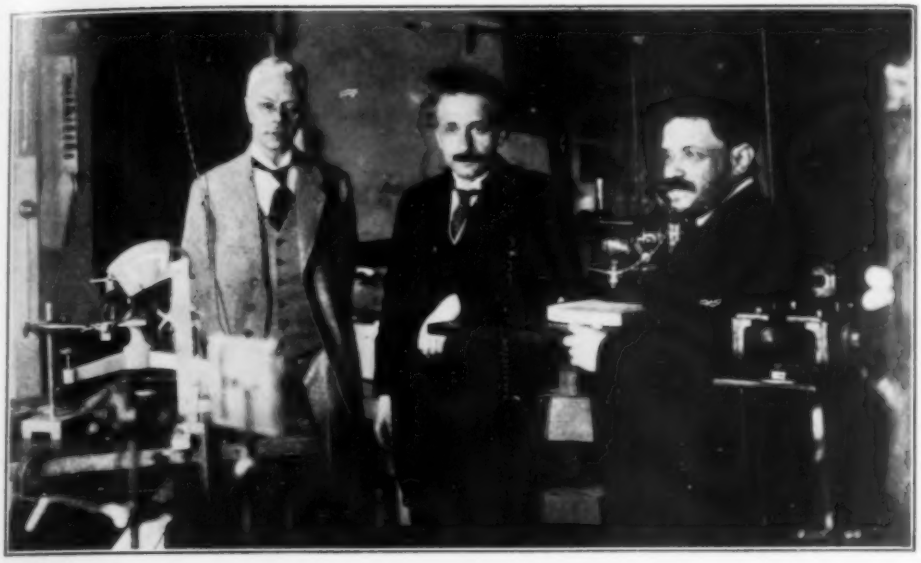
On May 25, 1935, Professor Pieter Zeeman reached his seventieth year, the age for retirement as an active professor at the University of Amsterdam. His friends and admirers throughout the world seized the occasion again to honor the discoverer of the famous "Zeeman effect," the twenty-fifth anniversary of this discovery having provided cause for a similar celebration in 1921. However, it required more than a quarter century for the full significance of this discovery to be realized. In 1921, there was still no systematic and satisfactory interpretation of complex Zeeman effects, but a few years later all became clear and the long hidden mysteries of spectral structures were explained. It is no exaggeration to state that Zeeman effects have disclosed many of the fundamental laws of atomic physics, finally brought law and order of extraordinary beauty and simplicity into the periodic classification of the chemical elements, and that they will always be the most important criteria for the analysis of spectral and atomic structures. These recent successes have greatly increased the appreciation of Zeeman's discovery among physicists the world over, and it becomes easy to understand their eagerness to do him honor. Now they have contributed 51 research papers to a jubilee volume, and donated a fund to be used for a scientific purpose to be indicated by Professor Zeeman himself. Those who are interested to know more about the man who inspires such adoration and international cooperation may read on.

Pieter Zeeman was born at Zonnemaire, Zeeland, in 1865. He studied at the University of Leiden, where he became assistant in physics in 1890, privatdozent in 1894 and lecturer in 1897. He was appointed professor of physics at the University of Amsterdam in 1900 and director of the physical institute in 1908. Zeeman and Lorentz shared the Nobel prize for physics in 1902.

The first attempt to detect a change in the lines of a spectrum when the source was acted on by a magnet appears to have been made by Faraday in 1862. Zeeman repeated this experiment in 1896 and had the good fortune to combine, for the first time, the use of sharp lines, a strong magnetic field and a powerful spectroscope, the three essentials for success. The first observations were made on the yellow lines of sodium, and a distinct widening of the lines was seen when the electromagnet was animated. Professor H. A. Lorentz, the brilliant theoretical physicist, predicted as a consequence of his electron theory that the edges of these widened lines would be polarized. This conclusion was immediately confirmed by Zeeman's experiments, and thus, many years before the electron was isolated, it was demonstrated that negatively charged particles were involved in the emission of spectral lines. Lorentz's theory also predicted that a spectral line observed parallel to the magnetic field would be a doublet of circularly polarized lines, while transverse observation would show a triplet of linearly polarized lines. These predictions were completely verified in 1897 by Zeeman, who thus became the first man to see a fully resolved magnetic pattern of a spectral line. At this point, it first became possible to determine from measurements on spectral lines the value of e/m.

Further investigation revealed, in addition to the simple triplets, many complex types of magnetic splitting. These were called "anomalous," and included the D lines of sodium which, when fully resolved, show 4 and 6 components (observed transversely). In spite of these disturbing anomalies, an underlying simplicity was indicated by the discovery of





ZEEMAN, EINSTEIN AND EHRENFEST

Preston's rule (1899), of Runge's rule (1907) and of the Paschen-Back effect (1912). A complete understanding of the complex Zeeman effect had to await the development of the quantum theory of spectra, suggested by Bohr (1913), but there is no doubt that it hastened this development.

According to the quantum theory, the maze of spectral lines characteristic of a chemical element originates from transitions between spectral terms or atomic energy states having much simpler properties than the lines. Experimental data on magnetic splitting were formally correlated with multiplet structure of spectra by A. Lande (1923), and the theory was soon elaborated to express displacement, polarization and intensity of all magnetic components of any spectral line in terms of quantum numbers associated with the two spectral terms involved. As a result, all the so-called anomalous Zeeman effects which had accumulated during more than a quarter century, but had remained uninterpretable, were suddenly explained, and it was lamented that more data were not available. They revealed simple order in the most complex and apparently chaotic spectra, correlated spectral terms with electron configurations in atomic structure and indicated that all atomic spectra are governed by the same simple but general rules.

Although the Zeeman effect has now been under investigation for nearly 40 years, there is little or no prospect that the field will ever become exhausted. Even now, Zeeman-effect data are entirely lacking for many complex spectra, for practically all spectra beyond the first stage of ionization, and for the infra-red and far ultra-violet. With modern improvements in technique, it is possible and highly desirable to extend the usefulness of this method.

Other fields to which the Zeeman effect has been successfully applied are the problem of hyperfine structure of spectral lines, analysis and interpretation of molecular spectra and the study of sunspot spectra which proved that the sun has magnetic polarity like the earth, and that the law of solar storms is similar to that of terrestrial cyclones.

WILLIAM F. MEGGERS

CHIEF OF SPECTROSCOPY SECTION
NATIONAL BUREAU OF STANDARDS

JOHN JAMES RICKARD MACLEOD

JOHN JAMES RICKARD MACLEOD, PHYSIOLOGIST

SEPTEMBER 6, 1876–MARCH 17, 1935

IT is not my purpose to write a history of Macleod, but rather an appreciation of the man and that for which he stood. I knew him chiefly in the days before he had become a historic figure as a partner in the discovery of insulin, an achievement which has made a new world for the legions of diabetics, present and future. The foundations for his share in this were laid in the man, in his training and in his environment long before the discovery was made, and it is in this more human side of which I wish to write—of Macleod the man, as his friends knew him, the genial Scotchman, who had turned his versatile and fertile mind with its ever fresh, almost boyish enthusiasm, to medical physiology in all its branches, physical and chemical, extending its roots down into organic and physical chemistry, bearing blossoms and fruits in its applications to the medical problems of health and disease and of healing. It was not an accident that so many of Macleod's disciples went into medical practice, ennobled by what they had learned of him; nor was it accidental that his chief discoveries were in the field of practical medicine. He appreciated the value of fundamental science, but his mind had a turn toward the practical, broadly conceived, and his interest was frankly in the medical rather than in the biological aspect of physiology and in chemical physiology rather than in biochemistry.

In 1903 Macleod was called to Cleveland to succeed G. N. Stewart as professor of physiology at Western Reserve University, and he accepted the call with youthful enthusiasm—he was only twenty-seven at the time, but somehow this youthful enthusiasm never seemed to age. He had graduated in medicine at Aberdeen; worked on purin metabolism at Leipsic, and assisted Leonard Hill in London. His immediate care was for teaching, and he captured the hearts of the students. He was and remained one of them; his lectures were crisp, clear, critical and convincing, his informal discussions inspiring; his laboratory courses practical. Physiology was a series of living, evolving problems generally with obvious practical bearing. Young men were attracted to him and worked as volunteers and as assistants on these problems, chiefly on circulation and respiration, and then on diabetes, which soon became Macleod's dominant research interest, especially when the development of new quantitative methods of blood sugar determination offered the possibility of checking, improving and extending the work of Claude Bernard.

His was a restless spirit; and although he was happy in the very busy life of teaching, research, writing and collaborating in several books, offices in scientific and medical societies, he developed a feeling that he might grow set and rusty by remaining too long in one environment. This made him susceptible to the repeated invitations of Sir Robert Falconer to go to Toronto and to assist in the contemplated reorganization of their medical teaching. He resisted for a time, but eventually succumbed, in 1918. He took his interests with him, and again a group of young workers gathered about him and were inspired by his enthusiasm for working on problems. Among these was Dr. Banting, who had thought out novel approaches for investigating the rôle of the pancreas in diabetes, a subject which still claimed a major share of Macleod's interest. This topic was at that time very much in the foreground; several workers were on the track of actively anti-diabetic extracts of the pancreas, but had failed to make convincing demonstrations. The solution appeared near, but further progress demanded new and fertile ideas, such as those that were in Banting's

mind; and also and equally a wide and intimate knowledge, obtainable only by long personal work in the field, a genuine familiarity with what had been done, and how far it had succeeded and why it had failed; a command of technical methods and their limitations, and a good measure of critical skepticism, to anticipate and to guard against false and premature conclusions, and withal persistent and enthusiastic faith in the feasibility of solving the problem; and finally, the ability to organize the forces to follow up promising leads, to clear away obstacles and to consolidate the success. This wide knowledge and experience of the subject, this judicious combination of enthusiasm and skepticism, this ability to lead, to organize, to inspire, Macleod possessed to a rare degree. I remember discussing the matter with him, when he felt certain that the problem had been solved, but when he was still restraining publication, till every possible doubt and objection had been met in advance. He was full of warm-hearted enthusiasm, tempered with caution. He was convinced that insulin had been discovered, he saw the new life that this opened to the diabetics, the benefits that should not be denied to them, that must not be delayed a moment longer than necessary. He had toiled and planned and toiled to eliminate the delays. He had struggled to save them the cruel disappointment of false hopes; his conscience had driven him in both directions; at last he felt that the sun of certainty was dawning. "Aye," he had tried to raise every objection that he could, together they had tested and met them all, he could think of no more. It was a "go."

The discovery of insulin is an outstanding instance in "team" research, by a partnership of workers where each contributes all his capital of special talents and experience to a common cause. In such a partnership it is generally of little use to inquire "who won the war," it was the partnership that won. It is of little use to argue what might have been the outcome without the partnership. Probably the discovery would not have been made then and there; there would have been delay at least, perhaps failure. The Nobel Prize Committee followed the course of wisdom when in 1922 they divided the prize equally between Macleod and Banting; and these acted generously as well as wisely when they in turn divided it with their junior partners, with Best and with Collip.

TORALD SOLLMAN
PROFESSOR OF PHARMACOLOGY AND MATERIA MEDICA, WESTERN RESERVE UNIVERSITY SCHOOL OF MEDICINE

A FIELD REPORT ON THE STRATOSPHERE FLIGHT FROM DR. BRIGGS

I AM writing this in camp on June 7 in the cliff-sheltered "bowl" in the Black Hills of South Dakota. Preparations for the 1935 stratosphere flight under the joint sponsorship of the National Geographic Society and the Army Air Corps are rapidly nearing completion. The great balloon is safely stored in its box in the center of the bowl. Over 1,800 cylinders of compressed helium gas are stacked nearby in neat rows awaiting the inflation. The gondola is mounted on a special truck ready to be wheeled under the balloon.

The gondola is of course the center of activity. Its shed is flanked by dark rooms and tents for unpacking and testing the apparatus for the flight—the cosmic ray tent, the spectrographic tent, the tent for ballast and balloon valves. Physicists are busy installing their instruments in the gondola, while balloon riggers are working on top attaching the suspension ropes, the ballast supports, the heavy batteries for operating the instruments and the great parachute for use in an emergency.

The gondola is a veritable floating

Photograph from National Geographic Society.

UNLOADING THE BALLOON IN THE BLACK HILLS

laboratory. For the study of cosmic rays it carries three electroscopes for measuring intensity at various altitudes, apparatus to count the rays coming in at various angles to the vertical, apparatus to measure the sudden "bursts" of cosmic radiation and a cloud chamber to photograph these bursts. It carries also a sky spectrograph and apparatus for measuring the temperature and pressure of the outside air and the brightness of the sun, earth and sky, together with cameras and broadcasting and navigating instruments. Suspended outside are the ultra-high frequency transmitters, the sun spectrograph and the spore-catching apparatus.

Two days more and the installation will be completed. Then with all apparatus on board the gondola will be rolled out and turned to "swing the compass," just as an ocean liner is turned through a complete circle to find whether or not in all positions the compass truly points to the magnetic north pole.

Six thousand pounds of fine lead shot

Photograph from National Geographic Society.

FINAL PREPARATIONS FOR THE STRATOSPHERE FLIGHT

GEORGE W. HUTCHISON, SECRETARY, DR. JOHN O. LA GORCE, VICE PRESIDENT, AND DR. GILBERT GROSVENOR, PRESIDENT, OF THE NATIONAL GEOGRAPHIC SOCIETY; AND CAPTAIN ORVIL A. ANDERSON, PILOT, OBSERVE THE ATTACHMENT OF THE LOAD ROPES TO THE SUSPENSION POINTS OF THE BALLOON.

Photograph from National Geographic Society.

AERIAL VIEW OF THE "STRATOCAMP"

in sacks weighing 150 pounds each will be carried as outside ballast. These sacks will be hung from the load ring of the gondola after it is finally placed below the great balloon. Each sack contains a blasting cap electrically connected to a switchboard so arranged that any sack may be opened by simply closing a switch. The heavy batteries are also hung in such a way that they can be dropped, each on its own parachute.

With everything so nearly ready, Captain Stevens and Captain Anderson are giving increased attention to the weather. Four complete weather maps are being prepared at the camp each day from information sent in by wire and radio. Ideal weather for the flight would be a cloudless calm day at the bowl for the take-off and clear skies and low surface winds for 400 miles to the southeast. We have not had suitable weather for the flight since we have been in camp and we are now waiting expectantly.

LYMAN J. BRIGGS

DIRECTOR, NATIONAL BUREAU OF STANDARDS; CHAIRMAN, SCIENTIFIC ADVISORY COMMITTEE OF THE NATIONAL GEOGRAPHIC SOCIETY—ARMY AIR CORPS STRATOSPHERE EXPEDITION

THE CELEBRATION OF THE CHEMICAL INDUSTRIES TERCENTENARY

IN the year 1635 John Winthrop, Jr., launched a chemical industry. The first governor of Connecticut, anxious to see the colonies independent of foreign sources of supply, projected the manufacture of salt, glass, potash, iron, tar, saltpeter, copper, alum, gunpowder and medicines. It is not surprising that most of his ambitious plans never reached fruition. When it is considered that Winthrop flourished during the early days of the phlogiston fantasy, the surprising thing is that he conceived such an elaborate program of chemical manufactures. And when it is realized that he actually started the production of salt, saltpeter and pine-tar, it is apparent that he was an artisan of no mean ability.

At its eighty-ninth meeting, held in New York towards the end of April, the American Chemical Society celebrated the three hundredth anniversary of Winthrop's salt manufactory. Emphasis was placed on the chronological development of our industries, and the growth of chemistry from alchemy was traced. Through a remarkably fortunate circumstance, 270 volumes from Winthrop's library have been preserved, and some fifty of these were exhibited at the Hotel

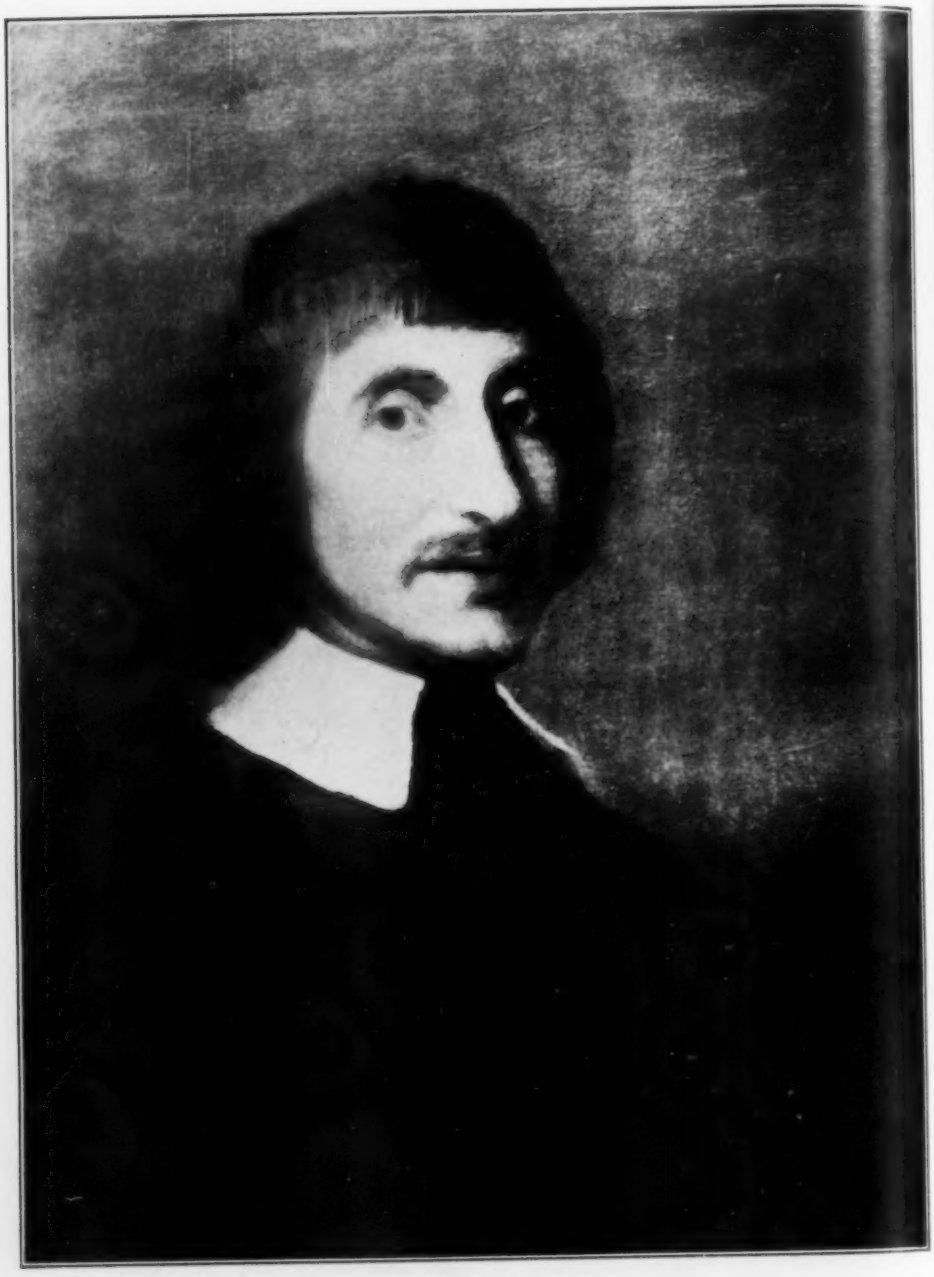
Pennsylvania. Their contents demonstrated graphically the aura of mysticism which surrounded early chemical art.

Attendance at the meeting surpassed all previous records, though not by so wide a margin as had been anticipated. The total registration was 5,105, representing 43 states and 17 foreign countries. Of these New York State contributed 1,697, and New York City 1,087. Of the 588 papers presented, only a few can be noted in this summary; it has been decided to select those which appear to be most significant in projecting the trend of research.

If any event on the program were singled out as being of superior significance, it would be the presentation of the Nichols Medal to Dr. Julius A. Nieuwland, of Notre Dame University. It is well known that he has worked for three decades on the chemistry of acetylene and its derivatives. One vast commercial application of these researches is Duprene. The peculiar superiority of this synthetic rubber, as Dr. Nieuwland pointed out in his address, lies in the fact that it contains chlorine in addition to carbon and hydrogen. It is not an imitation of nature's product, but it is better. It is non-inflammable and is more resistant to heat, oils and abrasives than natural rubber. The raw materials are limestone, coke, water and salt. This synthesis of a complex substance from simple ones is typical of the chemistry of the future. But to take full advantage of the possibilities that lie in this direction, we must learn how and why a catalyst works. For the benefit of those who complacently believe that chemistry has attained a high degree of perfection,

PROFESSOR ROGER ADAMS

OF THE UNIVERSITY OF ILLINOIS, PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY.



JOHN WINTHROP, JR.

Dr. Nieuwland stated bluntly that we will never really understand catalysis until we know how to make a potato from carbon dioxide, water and ammonia.

Dr. Frank C. Whitmore of Pennsylvania State College called attention to the fact that if Dr. Nieuwland had had his hands multiplied by government subvention, his contribution to our scientific knowledge would have been incalculably greater. The first is that hundreds of young, well-trained chemists are working in many of our industrial laboratories under comparatively incompetent supervision; careful planning would have had these men working instead under the direction of scientists of the caliber of Dr. Nieuwland.

PROFESSOR EDWARD BARTOW
OF THE STATE UNIVERSITY OF IOWA, PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY.

In these days of consumer-worship, the plea of Dr. A. C. Fieldner, of the U. S. Bureau of Mines, for conservation, seemed heretical. Fortunately our "visible" coal reserve, 3½ trillion tons, is so vast that its exhaustion lies in the distant future, but it is not so with oil. If the present rate of consumption is not increased, but is merely maintained, our reserve of 13 billion barrels will have been exhausted in 15 years. Dr. Fieldner suggested prolonging the life of petroleum by using coal for all ordinary heating and for stationary-power generation. Another obvious conservation measure would consist in stopping the conversion of petroleum into alcohol, even though for the time being this alcohol is cheaper than fermentation-alcohol.

Careful planning would permit agriculture, not the petroleum industry, to be stimulated by our increasing alcohol requirements.

On its side, the petroleum industry has taken a notable forward step by building up complex hydrocarbons from simpler ones. Dr. Vladimir N. Ipatieff, of the Universal Oil Products Company, described the polymerization of gaseous hydrocarbons to liquids of higher molecular weight. An accidental, but highly significant feature of the gasoline so produced is its high octane number. It enables engines of higher compression to operate without knocking, which means increased efficiency, and possible airplane speeds of 500 miles per hour. Thomas Midgley, Jr., of the Ethyl Gasoline Corporation, hazarded the guess that the 1,000 mile-an-hour plane is just around the corner.

Chemists have begun a serious attack on the problems of the construction industry. The exact mechanism of the setting of cement is not yet known, but experiments toward the solution of this problem were described. Other advances in the field include the expanding use of aluminum, nickel and stainless steel in buildings, and a synthetic stone of low density to permit increased height without impairment of structural strength.

In medicinal chemistry, several advances have been made in the elucidation of the structures of therapeutically important substances. Especially notable is the work of Drs. Craig and Jacobs, of the Rockefeller Institute, demonstrating the indole nucleus in the alkaloids of ergot. This should make possible the synthesis of these alkaloids, an accomplishment greatly to be desired, owing to the present variable activity of different preparations of ergot.

Robert R. Williams, of the Bell Telephone Laboratories, who has for many years pursued the study of Vitamin B_1 as an avocation, reported the presence of the thiazole nucleus in this vitamin. This is of unusual interest because thiazole has never before been observed in a natural product. Dr. Willard M. Allen, who received the Eli Lilly Award in Biochemistry for his work on progestin, gave an account of the isolation and the proof of the structure of this hormone.

Dr. Paul L. Kirk, of California, described his extension of the micro-analytical technique to the determination of calcium, urea and other clinically significant constituents of the blood. Analyses may now be carried out with as little as 0.03 cc, as compared with the former minimum requirement of one hundred times this quantity.

A discovery which promises to revolutionize the planting and harvesting of a portion of the grain crop was reported by C. F. Schnabel, of Kansas City. Young shoots of oats, wheat, barley and rye have two to five times the vitamin and protein content of spinach, lettuce, carrots, etc. Two or more crops of these young grasses can be grown each season. The vitamins are preserved by dehydration, and the pulverized product is palatable when mixed with other foods.

What of the future? This was answered in a rather breath-taking manner by Thomas Midgley. In fact, if a scientist of lesser achievements had made the predictions, he might well have been open to the suspicion of having his tongue in his cheek. Among the less startling developments which he expects are control of the growth of live stock by synthetic hormones, the end of colds, tuberculosis, diabetes and septicemia, and indefinitely prolonged life (if desired). In referring to the advent of a two-hour working day, Mr. Midgley was obviously speaking for the executive, for the most agile chemist can scarcely hope, for example, to complete a fractional distillation in this interval. And no self-respecting chemist of the future, I take it, would consider a single distillation a day's work.

THOMAS B. GRAVE